# FISCAL YEAR 1985 DEPARTMENT OF ENERGY AUTHORIZATION

## (Fossil Energy, Conservation and Renewable Energy)

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY DEVELOPMENT AND APPLICATIONS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

NINETY-EIGHTH CONGRESS

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# FISCAL YEAR 1985
# DEPARTMENT OF ENERGY
# AUTHORIZATION

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TUESDAY, FEBRUARY 28, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS,
*Washington, DC.*

The subcommittee met, pursuant to notice, at 9:35 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the subcommittee) presiding. Present: Representatives Fuqua, Ottinger, Lewis, Schneider, and Gregg.

## STATEMENT OF HON. DON FUQUA, A MEMBER OF CONGRESS FROM THE STATE OF FLORIDA AND CHAIRMAN OF THE SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS

Mr. FUQUA. The subcommittee will be in order. We continue our hearings, and today, they will be on the Department's fiscal year 1985 budget for conservation and renewable energy research and development. Our first witness will be Mr. Pat Collins, the new Under Secretary of Energy and the Acting Assistant Secretary for Conservation and Renewable Energy. Last year at our full committee hearings Secretary Hodel said that there would be a trend toward greater balance in the DOE research and development budget, and this year's DOE budget request confirms that trend. For conservation R&D, the administration has asked for an amount that is almost equal to last year's appropriation. And for solar and geothermal, the administration requests are about 80 percent of the funds authorized and 90 percent of the funds appropriated in fiscal year 1984. These budget requests are an important step toward providing the stability of funding needed to carry out effective R&D in conservation and renewable energy. And for the first time in a while, we have had a conservation and renewable energy budget request that we can work with, and we certainly appreciate that. I also note that the Department has provided excellent cooperation with the committee in multiyear plans in conservation. We look forward to receiving similar plans for the solar and geothermal programs in the near future. Following our questioning of the Under Secretary, we will have our first panel of outside witnesses on the DOE solar energy R&D programs.

[The opening statement of Hon. Larry Winn, Jr., follows:]

## OPENING STATEMENT

## THE HONORABLE LARRY WINN, JR.

ENERGY DEVELOPMENT AND APPLICATIONS SUBCOMMITTEE
HEARING ON FY 1985 DEPARTMENT OF ENERGY
CONSERVATION PROGRAM
FEBRUARY 28, 1984

THANK YOU, MR. CHAIRMAN, FOR THE OPPORTUNITY TO EXTEND MY WELCOME TO OUR WITNESSES TODAY ON THE FY 1985 DEPARTMENT OF ENERGY CONSERVATION AND RENEWABLE ENERGY PROGRAM BUDGET REQUEST.

I AM VERY PLEASED WITH THIS FY 1985 REQUEST LEVEL FOR THE CONSERVATION AND RENEWABLES PROGRAMS. IT IS A SIGNIFICANT INCREASE OVER THE AMOUNT REQUESTED BY THE DEPARTMENT OF ENERGY IN FY 1984. ALSO, IT COMPARES FAVORABLY TO THE AMOUNT APPROPRIATED BY CONGRESS LAST YEAR, PARTICULARLY IN VIEW OF OUR CONCERNS WITH THE BUDGET THIS YEAR.

THERE ARE TWO POINTS WHICH I WOULD LIKE TO MAKE RELATIVE TO THIS BUDGET. POSSIBLY SINCE THE BUDGET WAS ESTABLISHED THERE HAVE BEEN INNOVATIONS OR RE-EVALUATIONS WHICH HAVE

CHANGED PROGRAM PRIORITIES. IF SUCH IS THE CASE, I WOULD CERTAINLY PROVIDE FULL SUPPORT TO DOE FOR MODIFYING OUR LEGISLATION ACCORDINGLY-AT THE PRESENTLY REQUESTED FUNDING LEVELS. THE OTHER POINT IS THAT THE REQUESTED FUNDING LEVELS APPEAR TO BE TOTALLY ADEQUATE TO SUPPORT THE APPROPRIATE FEDERAL LEVEL IN THE SEVERAL PROGRAMS.

AGAIN, MR. CHAIRMAN, I AM SURE WE WILL FIND THE TESTIMONY WHICH WE RECEIVE TODAY HELPFUL AS WE PROCEED THROUGH THE BUDGET PROCESS.

THANK YOU.

Mr. FUQUA. Mr. Collins, we would be very pleased to hear from you today. And before we start—I understand that your Deputy Assistant Secretary for Conservation has had a very serious tragedy in his family, and I wish to express our deep sympathy to him and his family at this particular time.

## STATEMENTS OF WILLIAM PATRICK COLLINS, UNDER SECRETARY, U.S. DEPARTMENT OF ENERGY, ACCOMPANIED BY DONNA FITZPATRICK, PRINCIPAL DEPUTY ASSISTANT SECRETARY; JOHN MILLHONE, ACTING DEPUTY ASSISTANT SECRETARY FOR CONSERVATION; DR. ROBERT SAN MARTIN, DEPUTY ASSISTANT SECRETARY FOR SOLAR AND RENEWABLE ENERGY; AND DR. MELVIN H. CHIOGIOJI, DIRECTOR, OFFICE OF STATE AND LOCAL ASSISTANT PROGRAMS

Mr. COLLINS. Thank you very much, Mr. Chairman. We certainly appreciate the opportunity to appear, and the participation by the members and the staff of this committee and input to the process that led to this budget. I'd like to introduce my colleagues that are here with me today: Dr. Chiogioji, Dr. Bob San Martin, Donna Fitzpatrick, and John Millhone. Mr. Chairman, when I assumed the position of Under Secretary this past August, you remember there was a specific mandate from the Department and from the Secretary especially in the conservation and renewable area. We've refocused on these two programs and are very pleased that we have been able to come closer to the wishes of Congress and their appropriations and directions from the past year and, of course, we did that in concert with many of the members of this committee and their staffs. One of my first initiatives was establishment of a thorough review of ongoing and proposed programs to ensure that adequate funding would be available to meet the goals set by the Department and by this committee. The budget for these programs, I think, is consistent with our national energy policy plans, and I think that, just to go over it once again, we of course call for a mixed and balanced system of energy resources and a minimization of Federal control and involvement in energy markets while maintaining public health, safety, and environmental quality. As you know, as policies recognize, we need to have an adequate supply of energy at reasonable prices, and adequate supply certainly requires flexibility in the energy system and no undue reliance on any single source of supply. The goal of reasonable prices suggests economic efficiency within the energy system.

The fiscal year 1985 budget implements this strategy by supporting the development of a mix of technologies that can contribute to energy supply and end-use energy efficiency. We are concentrating our resources on applying Federal funds only where they're most effective, and in sponsoring research and development where the potential payoff is high, but where really private industry cannot be expected to pursue because the return on investment would require an exceptionally long time to be realized, or because the results are difficult to predict. These efforts will focus on improved dissemination of the results of R&D programs and expanded collaboration with the private sector. We also certainly recognize the important role of the national laboratories in the conservation and renewable R&D programs. We feel these laboratories are currently handicapped by the lack of specialized or up-to-date equipment in these programs, and our budget is an attempt to remedy that situation. Our proposed budget also reflects the commitment to support a truly varied mix of technologies, which is one of our key strategies in achieving our energy policy goals. We've stabilized the energy—the conservation and renewable energy organization, and we have taken the steps necessary to meet the mandatory staff floors. I would like to briefly summarize the highlights of our budget requests in each of the major program areas. In conservation, which means elimination of waste and careful, efficient use of our resources—it is a basic component of our strategy. As you know, the Secretary has said that conservation should be viewed as a resource that should be managed like any other resource. We're really focusing a great deal in this budget, Mr. Chairman, on increased energy efficiency as well as energy productivity. We also are taking an eye toward the consumers, the small business community, and actually the ultimate consumers in many cases who need to be affected through this technology transfer if we hope to realize the gains that we can in the conservation area. Of course, I think most of us know the record of achievement in the last 10 years, and basically, in round terms, between 1972 and last year, the Nation's energy efficiency has improved 20 percent. But Secretary Hodel and I think that we can and must do better, and certainly we are concerned that, to some degree, the stabilization of the prices of petroleum has led to some people taking their eye off that goal. I think that certainly higher energy prices and market forces have affected greatly this conservation, but I think the other good news from the last 2 years is that it appears that a permanent conservation ethic has begun to be established, and that is one of our goals as well. The fiscal year 1985 budget request in energy conservation programs under this subcommittee's jurisdiction, I am pleased to say, totals $89.1 million, roughly equal to last year's congressional appropriation. And, of course, that is contrasted to last year's request by the Department, which was $27.4 million. I think, in order to carry out these conservation efforts, we're requesting funding of about $29.2 million in buildings and community systems, $33 million for industrial program activities, and $26.5 million for the multisector program efforts, following the purview of this subcommittee. Just a couple of examples I would like to highlight for the committee we intend to undertake in fiscal year 1985: In our buildings and community systems program, research will be conducted not only in how to make building shells more energy efficient, but also to maintain acceptable indoor air quality levels in the tightest possible homes. We'll also be establishing a fellowship program to support building industry studies by university and industry researchers at the DOE national labs, and we're very excited about that involvement. In fact, we're also, of course, continuing Secretary Hodel's efforts to encourage the participation of students and faculty members from historically black colleges and universities as well as State and local government employees. Other research efforts will involve the development of improved burner designs and sophisticated combustion controls for industrial applications. Our energy conservation and utilization technologies will conduct research on development of materials that have great potential for improving the efficiency and the performance of the high-temperature processes. Five million dollars is also being dedicated to the inventions program to support the development of 50 to 75 energy-related, private sector programs, and I think that we have some excellent success stories to tell in that area. I think in the renewable area our fiscal year 1985 budget request supports the goals of fostering the adequate supply of energy at reasonable prices by helping promote a very mixed and balanced energy resource system. These proposals include funding under this subcommittee's jurisdiction of $190.8 million. This represents approximately 90 percent of the fiscal year 1984 congressional appropriation, and $88.5 million over the fiscal year 1984 request. In order to conduct those activities, to maintain the technical momentum that we would like to sustain, by the Federal research community and industry, we are requesting funding of $11.9 million for solar buildings energy systems, $47.5 million for photovoltaics, and $37.5 million for solar thermal. The funding request for the biofuels energy system is $28.1 million. In the wind and ocean program, we are requesting $23.3 and $3.5 million, respectively. In order to support a strengthened solar technology transfer, the Department is requesting fiscal year funding of $6 million, $27.1 million requested for geothermal energy R&D program, and $121,000 for the geothermal resource development fund.

I won't go through all those areas, but these are some of the highlights and some of the interests that I know have been expressed by this committee. In the photovoltaics area, research and development will be conducted into multilayered cells, which offer potential conversion efficiencies of up to 35 percent, and investigation of concepts that will allow for the operation of solar thermal equipment at temperatures in excess of 1,500 degrees will also be conducted in fiscal year 1985. Efforts in the biofuels area will include new genetics programs to develop wood resources with high yields, improved resistance to pests and disease, and lower nitrogen and water requirements, and improved energy characteristics such as higher Btu content and lower moisture content. Other research areas that withstand the severe ocean environment and identification of reservoirs suitable for extraction of energy from molten rock—these are just a few examples. Let me conclude, Mr. Chairman and members of the committee, by emphasizing that the budget submitted for fiscal year 1985 represents a balanced and objective approach to sustain the momentum that we have obtained the last 3 years, and I think this approach is very consistent with the goals and objectives of NEPP-IV. I think it's a sound and stable commitment to continue development of these technologies. And we're very pleased that this is, as we say, much closer to what this subcommittee has expressed in the past, and we appreciate your contributions to our efforts along this line. By the way, I do have a longer, formal statement, Mr. Chairman, and, with your permission, I would submit it.

[The prepared statement of William Patrick Collins follows:]

## STATEMENT OF
## WILLIAM PATRICK COLLINS
## UNDER SECRETARY
## U.S. DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Subcommittee:

I appreciate this opportunity to appear before you today and provide information on the FY 1985 budget request concerning the Department's energy conservation and renewable energy programs. The budget for these programs is consistent with and supports the goals and objectives of the Fourth National Energy Policy Plan (NEPP-IV), published in October 1983. I will summarize those parts of the Plan which are relevant to the subject of today's hearing, discuss related highlights of the FY 1985 budget request, and address the areas of interest identified in your letter of invitation.

## NATIONAL ENERGY POLICIES AND STRATEGIES

The overall goal of our national energy policy is to foster an adequate supply of energy at reasonable prices. This policy recognizes that "adequate supply" requires flexibility in the energy system, with no undue reliance on any single source of supply. The goal of "reasonable prices" suggests economic efficiency within the energy system, so that energy consumers, individuals, commercial and industrial users alike, are not penalized by economic rigidities introduced into the system by ill-advised governmental regulation. The strategies for achieving this energy policy goal are:

- to minimize Federal control and involvement in energy markets while maintaining public health and safety and environmental quality; and
- to promote a balanced and mixed energy resource system.

The FY 1985 budget request for energy conservation and renewable energy research and development programs implements these strategies by supporting development of a mix of technologies that can contribute to both energy supply and improved end-use efficiency. In allocating our resources, we are concentrating on applying Federal funds only where they are most effective; in sponsoring research and development (R&D) where the potential payoff is high, but which private industry cannot be expected to pursue because the results are difficult to predict or a return on investment would require an exceptionally long time to be realized.

Efforts will also focus on improved communication concerning the results of our R&D programs and on expanded collaboration with the private sector. Through these activities we intend to gain additional insights into industrial research priorities early in the federal planning process; and improve upon an already effective technical information program to better provide responsive and timely knowledge to interested parties.

In order to carry out this strategy we have proposed a budget for Conservation and Renewable Energy R&D programs under this subcommittee's jurisdiction which totals $279.9 million; $89.1 for Energy Conservation programs and $190.8 million for Renewable Energy programs. This request represents a 116 percent increase over the FY 1984 request, or approximately $150.2 million. These significant changes in our proposed budgets reflect the commitment to support a mix of technologies, which is one of the strategies to achieve our energy policy goal. We have also stabilized the Conservation and Renewable Energy organization and have taken the steps necessary to meet the mandatory staff floors established by the Congress.

I would like now to discuss each of our major program areas under the Office of Conservation and Renewable Energy and its related FY 1985 funding request.

## CONSERVATION

Energy conservation, which means elimination of waste and careful, efficient use of resources, is a basic component of our strategy. Our focus is on increased economic efficiency; that means investing energy dollars to achieve the greatest economic return possible. This will require investing in the development of new, energy efficient technologies which can result in a constant, long term reduction in energy consumption. Thus, we view energy conservation as a significantly important energy resource.

As we have recently stated in the NEPP and elsewhere, the goal of our national energy policy is to foster an adequate supply of energy at reasonable prices. This policy is rooted in the principle of freedom of choice to allow consumers to fulfill their energy needs in the manner they deem best. Conservation is one of the most effective and efficient resources that consumers have. It can be applied to all energy technologies and fuel types, and at every level of production, distribution and use. This Administration is supporting conservation through programs that rely on information dissemination and incentives, as well as on our research and development efforts. We are also supporting conservation by an approach to energy policy that relies on market forces and the consumers' right to choose for themselves how best to deal with changing market situations.

It is also crucial that government officials emphasize the place of conservation, as Secretary Hodel and I have done on many occasions. When there is talk of an energy glut it is important to stress that energy remains a large cost in our lives and that consumers need to base their conservation efforts on both the current price and the expected future price of energy. Whether the press is calling the current situation a glut, a shortage, or a balance, that is always the sound policy.

The effect of such a policy can be demonstrated from the recent past. The energy price increases which occurred after the 1973 oil embargo were of unprecedented magnitude. From 1973 to 1982, in real, inflation-adjusted terms, the average price of petroleum roughly tripled. The average price of natural gas, which can substitute for petroleum in many uses, rose similarly. Over the same period, also in real terms, the average price of electricity increased by more than 50 percent. Largely as a result of these price increases, energy use per constant dollar of Gross National Product has declined steadily. In the ten years between 1972 and 1982 the Nation's energy efficiency improved 20 percent. The resulting energy savings are equivalent to about 8 million barrels of oil per day--considerably more than the amount of oil which we now import.

Much of this conservation has been achieved in response to higher energy prices and market forces. Economic self-interest has motivated millions of consumers to reflect on their use of energy and to use the resources at their disposal more efficiently. Hence, reliance on the market is the mainstay of energy conservation policy, with the Department of Energy concentrating Federal funds on carefully-targeted technological research and development, with a special emphasis on technology transfer and communication with industry.

## FY 85 BUDGET REQUEST FOR ENERGY CONSERVATION

The FY 1985 budget request for Energy Conservation programs under this subcommittee's jurisdiction totals $89.1 million. Last year's request was $27.4 million. The FY 1985 request is roughly equal to the FY 1984 Congressional appropriation.

The Department's energy conservation research and development programs are designed to assist in the development of more efficient technologies and also alternative fuels to those based exclusively on fossil sources. Progress has already been made as a result of government/industry cooperation. For example, research into high temperature materials has developed special metal alloys which have demonstrated a four-fold increase in strength over existing technologies in extremely high temperature environments. Because energy efficiencies in heat engines increase with temperature, these materials promise advances in new engine designs. Though steady scientific progress is the expected result of such research, these efforts also hold the potential for technological discoveries that can make fundamental, rather than incremental, changes in national energy use.

I would like now to address the funding requests for our major program areas.

## BUILDINGS AND COMMUNITY SYSTEMS

The buildings sector accounts for approximately 36% of our total national energy consumption. In residential buildings the largest uses of energy are space heating, water heating and refrigeration; in commercial buildings the largest uses are space heating, lighting and air conditioning. Significant energy savings can be achieved by improving the efficiency of these and related building functions.

The FY 1985 budget request for the Buildings and Community Systems programs under this subcommittee jurisdiction is $29.2 million to conduct two major activities: (a) research and development into advanced technologies that will increase the energy efficiency of buildings; (b) information and technology transfer activities that will make the results of our R&D available to potential users.

We are requesting $12.2 million for the Building Systems subprogram in FY 1985 to support a variety of R&D, including: methods of making building shells more energy efficient; ways to maintain acceptable air quality in energy efficient buildings; methods to predict and measure the energy performance of buildings; means to retrofit existing buildings to make them more energy efficient; energy efficiency measures and their interactions with each other; and development of home energy rating systems.

The Technology and Consumer Products subprogram conducts research that will increase the efficiency of energy related equipment used in buildings. We are requesting $4.9 million for this subprogram in FY 1985. These funds will be used for research into advanced technologies which support development of more efficient, thermally activated heat pumps and advanced energy efficient lighting concepts.

The Community Systems subprogram supports research leading to the development of community-wide energy delivery and energy management sytems. A well known example of this technology is district heating. In FY 1985 we are requesting $2.0 million for this subprogram to be applied to the development of integrated community energy systems.

Our information and technology transfer activities for the Building and Community Systems program are carried out under the Analysis and Technology Transfer subprogram. We are requesting $4.5 million for this subprogram in FY 1985. These funds will support continuation of our cooperative efforts with the International Energy Agency and will be used to undertake two new technology transfer initiatives. The first initiative will establish an Energy Efficient Buildings Center, which will display new materials, technologies, and equipment and serve as a clearinghouse for R&D results and innovative technologies. The second initiative will establish a fellowship program that will support building energy studies by university and industry researchers at the DOE national laboratories. A special effort will be made to encourage the participation of students and faculty members from Historically Black Colleges and Universities, and State and local government employees.

Finally, we are requesting $2.5 million for capital equipment in support of the Buildings and Community Systems program in FY 1985. These funds will be used for roof testing equipment at the Oak Ridge National Laboratory, for model building simulation equipment, and to replace out-moded test equipment at DOE national laboratories.

## INDUSTRY

The FY 1985 budget request for Industrial programs is $33.3 million to carry out work in four subprograms: Waste Energy Reduction, Industrial Process Efficiency, Industrial Cogeneration, and Implementation and Deployment. Most of the activities in the industrial area are carried out by private institutions operating under cost-shared or cooperative agreements with the Department.

The Waste Energy Reduction subprogram supports research and development programs including: improved combustion efficiency through oxygen enrichment, improved burner designs, and sophisticated combustion controls; development of industrial heat pumps, high temperature recuperators, and ceramic materials for heat exchangers; and research into waste materials utilization and $CO_2$ recovery and utilization. We are requesting $12.4 million for this subprogram in FY 1985.

The Industrial Process Efficiency subprogram includes R&D for thin strip casting of steel, inert anode materials, advanced heat processing sensors and control systems, membrane separation systems, and black liquor gasification (burning of paper industry waste). We are requesting $8.0 million for this subprogram.

The Cogeneration subprogram supports research into coal-fired Brayton cogeneration systems, coal and water slurry fired diesel cogeneration systems, and a thermionic burner system. We are requesting $3.2 million in this area.

Also, in addition to the R&D activities to be funded by the FY 1985 request, there are a number of activities which are ongoing and supported by prior year funding. These projects include fluidized-bed waste heat recovery systems, utilization of waste materials, sensors and control systems, separation systems, and cogeneration component research.

The Implementation and Deployment subprogram continues support for the Energy Analysis and Diagnostic Centers at ten universities, carries out the Congressionally mandated Industrial Energy Efficiency Reporting program, and supports a number of new initiatives in the area of technology transfer. These new initiatives include fellowships for university and industrial researchers at the national laboratories, and the establishment of a national information center for industrial energy conservation technology and R&D results. Altogether, we are requesting $3.5 million for this subprogram. Finally, the FY 1985 budget requests $4.4 million for new equipment and instrumentation to enhance research activities at the DOE national laboratories.

## MULTI-SECTOR PROGRAMS

The Multi-Sector Program includes the Energy Conversion and Utilization Technologies (ECUT) Program, the Energy Related Inventions Program, and the National Appropriate Technology Assistance Service. The FY 1985 budget request for Multi-Sector includes $21.5 million for ECUT and $5.0 million for the Energy Related Inventions Program.

The FY 1985 budget request for the ECUT program is $21.5 million to conduct research activities to expand and improve the generic information and technology database that supports initiatives by both government and private industry to improve the efficiency of energy conversion and utilization systems. ECUT research programs are oriented toward basic research and cross-cutting R&D common to more than one energy-consuming sector. They also provide predictive models and design tools useful to the private sector in achieving greater energy productivity. The requested funding will be used to conduct research in four areas: Combustion and Thermal Sciences, Materials Sciences, Biocatalysis, and Tribology.

The budget requests $5.8 million for the Combustion and Thermal Sciences subprogram. Combustion research provides analysis and measuring techniques used to understand the thermochemical and related processes that take place in the combustion of fuels and in the conversion of released thermal energy to work. The results of this research are used to develop efficient, clean, and reliable combustion systems and devices.

Thermal Sciences research develops improved thermodynamic analytical capabilities and experimentally validated computerized data bases, both of which are used to help increase overall heat transfer coefficients, reduce heat transfer surface area requirements, and minimize vibration induced by fluid flow through heat exchangers.

The $6.0 million requested for Materials Sciences research will be used to investigate high-temperature materials, lightweight materials, and corrosion resistant materials. Certain materials, such as Long-Range Ordered (LRO) Alloys and Intermetallic Compounds, materials with ordered atomic structures, have great potential for improving the efficiency and performance of high temperature processes, but have not been utilized because of their characteristic brittleness. Research on all these fronts will be expanded in FY 1985.

The $2.0 million requested for Biocatalysis research will be used to establish a technology base for new techniques to manufacture industrial and commercial chemicals using biological systems analogous to conventional processes in chemical engineering.

The $3.0 million requested for the Tribology Program includes research on lubricants, friction and wear of ceramics, coatings on machine tools that reduce wear and last longer, and refinement and quantification of friction energy losses in the U.S. economy.

We are also requesting $4.7 million for the following efforts: to provide seed money for innovative concepts for alternative fuel use and improved energy efficiency in energy conversion, storage, and end-use; to administer and direct the ECUT program; and, to provide capital equipment to replace currently outmoded equipment at DOE national laboratories to support a number of new technology transfer initiatives.

The Energy Related Inventions Program was established to evaluate the technical merits of energy-related inventions submitted to DOE and to provide technical assistance or grants to further develop promising inventions. To date, 164 inventions have been awarded grants totalling $12.8 million. Of the 164, 35 have entered the marketplace with sales totalling $178 million, creating 756 jobs. In FY 1984, approximately 40 grants will be awarded. The FY 1985 budget request of $5.0 million for the Inventors Program will be used to support development of an anticipated 50 to 75 private sector inventions.

The Department is not proposing funding for the National Appropriate Tehnology Assistance Service in FY 1985 because the $2.0 million appropriated in FY 1983 and FY 1984 is sufficient to support this program through FY 1985.

## STATE AND LOCAL PROGRAMS

No funding is being requested for the Energy Extension Service. The Administration considers the continuing transfer of Federal energy R&D results to consumers and the private sector a high priority. Accordingly, DOE will make information from Federal

R&D efforts available to states and local governments, allowing them to fund and operate their own energy conservation and information dissemination programs. States have become increasingly able to develop and implement the activities established by this program, eliminating the need for continued Federal funding. On the other hand, the President's budget does include grant funding for other conservation activities implemented through the States. These activities were selected for funding because they most directly provide for the conservation of energy through the installation of energy conservation equipment and materials, thus enabling those recipients to improve their energy efficiency.

## RENEWABLE ENERGY

The FY 1985 budget request for Renewable Energy programs supports the goal of fostering an adequate supply of energy at reasonable prices by helping to promote a balanced and mixed energy resource system.

The Departmental proposals regarding Renewable Energy research reflect a tangible commitment by DOE to conducting those activities necessary to sustain the technical momentum established by the Federal research community and industry. Within this family of energy options, the progress has in many cases represented a steady procession of success in improved efficiencies; development of materials with unique structural, chemical, or thermodynamic properties; and incremental improvements in the reliability and durability of critical components. Frequently, these more measured advances have been matched by breakthroughs which both expand the frontiers of our knowledge and open up entirely new paths of development.

To use Photovoltaics as an example, in 1980, multi-junction cell research was in the initial stage of conceptualization. This research process has advanced to the point where recent experimental efficiencies of 22 percent were recorded. Equally important is the fact that research at the Solar Energy Research Institute (SERI) and at industrial laboratories has significantly increased understanding of the basic photovoltaic effect. Today, scientists and engineers openly debate the most suitable concepts to reach conversion efficiencies of 35 percent; a figure not considered attainable some three years ago.

We are confident that the pace of concept definition, innovation, and technology maturation will remain swift within the program proposed by DOE.

## FY 1985 BUDGET REQUEST FOR RENEWABLE ENERGY

The FY 1985 budget request for Renewable Energy programs under this subcommittee's jurisdiction is $190.8 million. This is approximately 90 percent of the FY 1984 Congressional appropriation and $88.5 million over the FY 1984 request of $102.3 million.

In formulating these proposals we have considered a number of factors including the degree of scientific and technical risk of specific activities, the overall stage of technology maturity, the degree of industrial development, and the nature and magnitude of potential payoffs should these technologies be deployed by industry.

The proposals before you today reflect conscious decisions to maintain a proper balance between definition and development of renewable resources, applied research, and sufficient exploratory development necessary for continued resolution of critical technical and engineering issues.

I would like to now discuss briefly our proposals in each of the major Renewable Energy technologies.

## SOLAR BUILDING ENERGY SYSTEMS

Solar building energy technologies employ direct and indirect solar radiation to provide heating, cooling, and daylighting for buildings.

In FY 1985, the budget request for Solar Building Energy Systems is $11.9 million. Key activities include $7.2 million for Materials and Components Research, $3.2 million for Heat Transfer Systems Analysis, $1.3 million for Thermal Sciences Research, and $0.2 million for Capital Equipment.

In Materials and Components Research, emphasis will be placed on the design and testing of thin-film polymer materials to develop low cost, durable photothermally stable polymer foil collectors. Research on evacuated tube, compound parabolic concentrating (CPC) collectors will focus on cost effective materials and designs to generate steam within the collector and to analyze the characteristics of in-situ vapor generation. Research on promising desiccant materials, such as manganese oxides and polymers, will be augmented by design and cyclic testing of full-scale dehumidifiers.

In Heat Transfer Systems Analysis, testing and analysis of prototype components will be undertaken on system control and integration techniques that have the potential for increasing performance with little increase in cost. Building load responses to solar input transients will be conducted on residential and commercial buildings. Research to further understand natural convection distribution systems, to characterize the impact of building space conditioning loads upon utility demand profiles, and to determine the effectiveness of cooling and daylighting technologies will also be conducted.

Finally, in Thermal Sciences Research, basic thermodynamic cycle analyses to determine the most promising advanced concepts for solar heating and cooling, particularly solar salt gradient research, will be undertaken.

## PHOTOVOLTAIC ENERGY SYSTEMS

Photovoltaic technology directly converts solar radiation through cells to an electric current.

For FY 1985, the Department is requesting $47.5 million. This includes $31.0 million for Materials Research, $10.5 million for Collector Research, $5.0 million for Systems Research, and $1.0 million for Capital Equipment.

In Materials Research, work will focus on single-junction thin-film cells, advanced high-efficiency concepts, advanced silicon sheets and innovative concepts. For single-junction thin film cells, research will concentrate on increasing cell efficiency to 15 percent, as well as continuing to improve cell stability and lifetime.

Advanced high-efficiency concepts will focus on the development of multi-junction photovoltaic cells which have the potential to achieve high conversion efficiencies of up to 35 percent. Activities will include the fabrication of multiple cells on silicon wafers, the mechanical and optical coupling of gallium aluminum arsenide and silicon, and the stacking of polycrystalline cells.

Research will be conducted on the development of technology such as the dendritic web process to overcome the low yield and quality control problems inherent in state-of-the-art batch production technologies. In support of cell materials research, the Department is proposing to upgrade the capabilities of the Device and Measurement Laboratory at SERI.

The Department proposes to complement the materials research activities with innovative concepts and a university research program that draws upon the creative genius of the nation's universities, private research laboratories, and small businesses. Seed money will be provided to test the best new ideas provided by these organizations.

In Collector Research, efforts will relate to both flat plate and concentrator modules. Flat plate collector research is aimed at increasing the efficiency of baseline crystalline silicon cells through improved module coatings and low-cost metallic and nonmetallic conductors. Concentrator collectors research will be focused on silicon and advanced silicon gallium arsenide cells which can potentially achieve efficiencies of 20 to 23 percent.

In Systems Research, the major focus will be on increasing module reliability and life expectancy through life testing and the identification of failure mechanisms.

## SOLAR THERMAL ENERGY SYSTEMS

Solar Thermal technology employs concentrated radiant solar energy to produce heat or electricity or both.

The FY 1985 budget request for Solar Thermal Technology is $37.5 million. The request includes funding of $8.9 million for Materials and Components Research, $4.5 million for Concentrator Research and Development, $7.1 million for Central Receiver Research and Development, and $0.5 million for Capital Equipment.

Materials and Component Research will include experiments to establish the stability and physical properties required for high temperature heat transfer and containment materials. Polymer materials for potentially low-cost and light weight concentrators will be developed and evaluated.

In Concentrator Research and Development, low-cost, high performance concentrator concepts based on stretched metal membranes, reflecting polymers, light weight graphite structures, and holographic lenses will be experimentally evaluated.

For Central Receiver Research and Development, research will be undertaken on advanced concepts that show promise of attaining the substantial performance gains expected in operating at temperatures in excess of 1500°F. Innovative concepts employing solid particles, liquids, and hot gases as the heat transfer medium will be evaluated. The testing and evaluation phase of the Barstow 10MWe Central Receiver Pilot Plant will be completed and the power production phase will be initiated and evaluated.

In Distributed Receiver Research and Development, the Department proposes a one-time activity to cost share the development of first generation Stirling and Brayton engines. Additionally, DOE will operate the Distributed Receiver Test Site to provide a unique test bed for industrial interests.

## BIOFUELS ENERGY SYSTEMS

Biofuels technologies are potentially capable of converting organic feedstocks into liquid, gaseous, or solid fuels. The Department's Biofuels Program incorporates the activities formerly managed separately as Biomass Energy Technologies, Alcohol Fuels research, and Energy from Municipal Wastes.

The FY 1985 budget request is $28.1 million. This includes $4.2 million for Short Rotation Intensive Culture, $6.2 million for Feedstock Production research, $7.0 million for Thermochemical Conversion, $6.6 million for the Regional Biomass Program, and $1.0 million for Capital Equipment.

Short Rotation Intensive Culture research will focus on woody species selection and improvement. A genetics program to provide for the development of species with increased yields, improved resistance, lower nitrogen or water requirements, and improved energy characteristics will be undertaken.

Feedstock Production research will be conducted to better define the energy potential of herbaceous and aquatic crops. For herbaceous crops, the Department will conduct species screening and cultural research to improve energy productivity. Aquatic species research will focus on microalgae screening and genetic selection to improve oil product synthesis, increase growth rates, improve temperature tolerance, and enhance harvestability.

In Thermochemical Conversion, research is focusing on process improvements in the conversion of agricultural residues and woody and herbaceous crops into liquid and gaseous fuels. Tests on process research gasifiers, thermochemical reactors and pyrolysis will be conducted. Research on liquid and gaseous fuels extraction from municipal solid waste (MSW) will also be conducted. Direct liquefaction research will evaluate the viability of wood as a feedstock for liquid fuels production.

Biochemical Conversion efforts will focus on acid and enzymatic hydrolysis of cellulosic materials to produce ethanol with improved conversion and economic efficiencies. Research will be conducted on improving alcohol/water separation techniques, and on anaerobic digestion of cellulosics. A 25 ton per day acid hydrolysis reactor will begin operation and the Refuse-

Conversion-to-Methane (Refcom) facility at Pompano Beach will evaluate methane production using sewage sludge combined with municipal solid waste.

-The Department proposes to fund the Regional Biomass Program to serve as a valuable point of technical integration in the complex field of biofuels. These regional programs will make available research and other information concerning biomass feedstock resources, feedstock conversion technologies, and potential end-use applications.

## WIND ENERGY SYSTEMS

Wind energy involves the conversion of the kinetic energy in moving air masses into more useful forms, such as electricity or mechanical energy.

The FY 1985 budget request for Wind Energy Technology is $23.3 million. The budget includes $8.8 million for Aerodynamics Research, $7.7 million for Structural Dynamics Research, $0.7 million for Systems Analysis and Evaluation, $1.7 million for operation of the Small Systems Test Center at Rocky Flats, $4.2 million for the MOD-5 Multi-Megawatt Wind Turbine Program, and $0.2 million for Capital Equipment.

In Aerodynamics Research, research will be conducted to characterize the effects of dynamic stall and unsteady flow for both small and large wind turbines (horizontal and vertical axis) by development of 3-dimensional airflow models. Investigations of turbine performance degradation under actual operating conditions will be performed along with studies of airfoil lift and drag properties.

In Structural Dynamics, research focuses on the accurate prediction of structural loads to the extent necessary to design long-life wind turbines. Research and cooperative test programs using commercial machines and MOD-2 turbines will test models for prediction of natural resonant frequencies. Fatigue life models incorporating turbulence, turbine operating strategy and aeroelastic loads will also be developed.

Improved vertical and horizontal test beds will be developed to replace the outdated MOD-0 and 17-meter Darrieus machines designed in the early 1970's. These experimental test beds will accommodate advanced research and testing in multiple-chord airfoils, tailored aerodynamics, variable speed generators, rotor control techniques, and rotor augmentation.

The Small Systems Test Center at Rocky Flats will provide testing and engineering support to industry on a fee-paid basis.

The MOD-5 Multi-Megawatt Wind Turbine activity will focus on design and development testing of the MOD-5B wind turbines.

## OCEAN ENERGY SYSTEMS

Ocean energy technology involves the extraction of energy from ocean waves, currents, tides, salinity gradients, and thermal gradients.

The FY 1985 budget request is $3.5 million. The budget includes $1.0 million for Materials and Structures Research, $1.4 million for Thermodynamic Research and Analysis, $0.6 million for Experimental Verification and Testing, and $0.5 million for Environmental and Oceanographic Research.

In Materials and Structures Research, activities will center on the development of materials that can withstand the severe ocean environment. Fiberglass reinforced plastic (FRP) pipe will be tested to determine fatigue parameters. Cold water pipe, platform, and foundation deployment and installation techniques will be developed to determine fail-safe installation methods for Ocean Thermal Energy Conversion (OTEC) components.

In Thermodynamics Research and Analysis, supporting research will include gas kinetics, material stress and fatigue, and heat exchanger enhancement.

In Experimental Verification and Testing, research will concentrate on the development and experimental verification of generic models at the Seacoast Test Facility. In Environmental and Oceanographic Research, large water displacement effects and coastal zone interactions will be studied.

## SOLAR TECHNOLOGY TRANSFER

The Solar Technology Transfer program provides a mechanism to transfer research results, experiences and "lessons learned" to many groups and individuals within the private sector research and manufacturing communities. A reciprocal process through which industrial priorities are considered early in the Federal planning process, technology transfer is a vital link between the public and private sectors in the research and development process.

The program request for FY 1985 is $6.0 million. This request includes $3.2 million for Solar Technical Information and Mandated Reports, $2.2 million for the Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS), $0.4 million for Technology Transfer Assessments, and $0.2 million for Seminars and Workshops.

Technology Transfer Assessments will be undertaken in cooperation with industry to evaluate technology transfer methods in meeting private sector needs. Various information dissemination methods, seminars/workshops/conferences, cooperative research projects, cost-sharing, fee-paid user test facilities, and technology transfer centers are among the mechanisms that will be reviewed.

A series of Seminars and Workshops will be funded in order to provide an interactive participatory environment between the DOE and the private sector. Significant research results and technical accomplishments will be presented through these forums.

## GEOTHERMAL

Geothermal energy involves the use of the natural heat of the earth and its conversion to a useable energy form.

The FY 1985 budget request is $27.1 million. This request includes $3.5 million for Geopressured Resources; $5.5 million for Hot Dry Rock research; $9.9 million for Hydrothermal research; $4.4 million for Hard Rock Penetration research; $1.4

million for Magma Energy Extraction research; $1.0 million for Technology Transfer; $0.4 million for Capital Equipment; and $1.0 million for Program Direction.

The Geopressured Resource activity will focus on flow testing of Gulf Coast geopressured aquifers and the collecting and archiving of the long-term flow data. In cooperation with industry, DOE will investigate the potential performance of a wellhead electric generator suited for operation at this type of geothermal well.

In the area of Hot Dry Rock research, fracturing experiments at Fenton Hill will provide a basis for verifying the technical feasibility of this geothermal energy extraction technique. Technical analyses will be conducted to predict the chemical and physical behavior of crystalline rocks.

In Hydrothermal research, activities are proposed to address brine injection, reservoir definition technology, heat cycle research, Geothermal Test Facility operation materials testing, and deep scientific drilling. A very deep well will be drilled into a known tectonic spreading center to determine the depth of hydrothermal convection. Fracture mapping techniques to locate natural fracture systems within hydrothermal reservoirs will be field tested. The Geothermal Test Facility will provide a field site for testing of pumps, heat exchangers, turbines, and materials capable of lowering costs and increasing equipment life.

In Hard Rock Penetration research, activities will include rock/cutter interaction tests; testing to identify post-circulation material that will reduce the risk of damaging the well; design of a lost circulation zone mapping tool for characterizing geothermal wellbores; development and testing of a prototype logging tool to measure downhole parameters.

In Magma Energy Extraction research, activities will include the preliminary characterization of selected magma reservoirs to evaluate technology boundaries and the potential for magma energy extraction.

In Technology Transfer, a variety of activities including conferences, seminars, publications, and cooperative technology reviews will be undertaken.

## GEOTHERMAL RESOURCE DEVELOPMENT FUND

The Geothermal Resource Development Fund (GRDF) was established to broaden the geothermal energy technology base through guarantying risk capital for private sector development of several state-of-the-art facilities.

The FY 1985 budget request is $0.1 million for GRDF program direction to review and evaluate pending loan applications and for loan monitoring.

## CONCLUSION

These energy conservation and renewable energy technologies show enormous potential for the future. Collectively, their potential applications make them highly attractive candidates for private sector development and deployment. These technologies promise increased diversity and end-use efficiency and should serve to promote increasing competition within the energy marketplace. Their development will also enhance the ability of the private sector to rapidly respond to unpredictable fluctuations in supply and price of conventional fuels.

The program presented for your review today represents a sound and stable commitment to the continuing development of these technologies. We are confident that our proposals will increase understanding of the potential for virtually all of the most promising energy conservation technologies and renewable energy options, and will substantially contribute to the base of technical information required for informed decision making.

I would be pleased to answer your questions at this time.

Mr. FUQUA. Thank you very much. On the OTEC program, you've requested funds for this program. Has a multiyear plan been prepared to guide the research?

Mr. COLLINS. Mr. Chairman, of course this is a new commitment for us in this area, and it has not been prepared yet, but we do plan to have that completed by August of this year.

Mr. FUQUA. On the Energy Extension Service, the Department's proposing several new technology transfer initiatives, but there's not any funding for the primary existing technology transfer function, such as the Energy Extension Service. Why, when you have something in place, do you choose not to use that and go to something else?

Mr. COLLINS. Well, Mr. Chairman, we certainly are pleased that we do have initiatives in the weatherization and the schools and hospitals program this year, which is the first in the last 3 years. Primarily, the benefits go directly to the recipients. In the areas of the Energy Extension Service, we think that this is an area that possibly the States could play a stronger participatory role in, and we would like to—we, quite frankly, have a mixed review on how this is done around the country, too. Some of the States are doing a fairly good job along this line, but, unfortunately, some are not. And as a result of that, we wanted to try a more coordinated approach with our technology transfer initiatives.

Mr. FUQUA. On the wind program, what are the fiscal year 1984 funds required to close out the MOD-5 program, MOD-5A?

Mr. COLLINS. Yes, sir. I'd like to defer to Dr. San Martin.

Dr. **San Martin**. Mr. Chairman, the closeout of the multimegawatt MOD-5A General Electric wind turbine contract is in negotiation at this particular time, so that I cannot give you an exact number, but we should be able to determine what that is in the negotiations by the end of next month.

[Material referred to follows:]

Negotiations to close out the contract are still underway between NASA and GE. We anticipate final modification of the contract to be completed in May or June. We will notify the Committee of the final disposition of the contract at that time.

### CLOSE-OUT OF MOD 5A

Closeout costs for the General Electric MOD 5A multi-megawatt wind turbine development contract will amount to $1.5 million.

Mr. **Fuqua**. Well, Bob, what do you plan to do if you have any unexpended funds left over?

Dr. **San Martin**. Mr. Chairman, we have proposed that a portion of those MOD-5A funds, specifically $3 million of what had been allocated to that particular activity, be deferred for use in 1985, and that has formally been presented——

Mr. **Fuqua**. To carry it over?

Dr. **San Martin**. Yes, sir. And there will be, for the remaining fund, some closeout cost involved. And if there are any funds that are actually recouped in that particular process, then we would have to address whether it would be best to address some important technical issues that remained in the wind area and potentially apply it to another contract, if it's needed, or again consider the possibility, if it appears prudent, to defer the use of the funds until next year.

Mr. **Fuqua**. On the MOD-5B, have you proposed a cost-sharing plan for that particular project?

Dr. **San Martin**. Mr. Chairman, we have held steadfast with the MOD-5B contractor on the directions we were given by Congress to pursue a 50/50 cost share plan. We are anticipating a response in the very near future from the contractor, and we only suspect at this time that they may be proposing something different than what was originally intended.

Mr. **Fuqua**. Have you proposed a deadline for them to come up with a proposed cost-sharing plan?

Dr. **San Martin**. We have not established a contractual deadline, Mr. Chairman, at this particular point in time, but we have stressed upon the contractor that we need a formal response from them very shortly.

Mr. **Fuqua**. So the project hasn't been terminated then?

Dr. **San Martin**. No, sir, Mr. Chairman, the project has not.

Mr. **Fuqua**. Well, you have some large increases in aerodynamic and structural research, and I was wondering what the consequences of delaying or slowing down these increases, and what are you doing in cooperating with other parts of DOE and other Federal agencies that have been doing some work in this, particularly like NASA that does a lot of work in aerodynamics, and I know you have some materials programs in other functions of DOE. My question is really, I hope you're not duplicating something that's already available or being accomplished somewhere else.

Mr. **Collins**. Mr. Chairman——

Mr. **Fuqua**. Yes?

Mr. **Collins**. We do have a formal structure to review that, and we think that's extremely important as well. We think that structure is effective now. We're reviewing, of course, things like this constantly to be sure that we do not get into that area.

Dr. **San Martin**. Mr. Chairman, this is an area that we have been very fortunate to have received very good support from NASA in pursuing these areas, and it is based on the advice we have received from NASA plus other independent consultants that we propose addressing an area which I have to admit has been slightly neglected in the past few years in the wind budget, and it's beginning to become a critical problem to the wind industry to address some of the uncertainties that are proposed for resolution in this 1985 budget.

Mr. **Fuqua**. Secretary Collins, does the Department believe that a permanent laboratory facility should be built at SERI? And are you planning to request any funds for such a facility? That's been hanging around for several years now.

Mr. **Collins**. That's correct, Mr. Chairman, and we understand the situation at SERI, of course, is, in essence, you've got a scientific operation and what was an office park, in essence, and certainly not of the quality of facilities recently finished in Idaho and in other places. We are just about ready to occupy our first structure there, and, as this committee is well aware, there has been some discussion of a second facility, and we have not included that in this year's budget but we're proceeding along with the first one, which should be scheduled to be occupied in February, and I think it will be within a month.

Mr. **Fuqua**. Has the State of Colorado made any suggestions about taking back their land? It is my understanding when that land was first donated it was with the agreement that the Government would build a permanent structure on that property, and that was part of the condition for the donation, as I recall.

Dr. **San Martin**. You're exactly correct, Mr. Chairman. The formal transfer of the land from the State of Colorado did take place prior to the beginning of construction of the first facility, and, in fact, the agreement that has been reached makes available for use by SERI the originally intended large plot of land. There is a requirement that if immediate development does not take place in the intended area, that a portion of the land could revert back to the State. I would be surprised, Mr. Chairman, if that does occur.

Mr. **Fuqua**. Of course, the agreement didn't require that it be a Taj Mahal built there, either.

Dr. **San Martin**. No, sir, Mr. Chairman.

Mr. **Fuqua**. Mr. Lewis?

Mr. **Lewis**. Thank you, Mr. Chairman. Mr. Secretary, Congress has continued to reexamine the need for energy tax credits and the extension thereof. Does the Department have a position on this at this time?

Mr. **Collins**. Well, Mr. Lewis, from an energy standpoint, we certainly recognize that these credits have played a very important role in the development of an infant industry, and we recognize that role, and from just an energy standpoint we are trying to enlighten all of our colleagues within the administration within this process about the role that has played and could play in the future. Presently, we are in the intra-administration discussions on this and have been for some time and generally would be looking for comment on a specific vehicle and not a general concept.

Mr. LEWIS. It's my understanding that Mr. Stockman is opposed to these types of things. Will he prevail or will the Department of Energy prevail, or is there a compromise position somewhere down the line?

Mr. COLLINS. Well, through the Cabinet council process, Mr. Lewis, we'll have a consensus position, I would assume, that will come out of that process, probably related to some specific piece of legislation that may come to the floor either in this body or the Senate.

Mr. LEWIS. In previous years the Department has provided the committee with gold books indicating their milestones and things of that nature. Do you have plans to do that this year?

Mr. COLLINS. Well, the color won't be the same, but——

Mr. LEWIS. Well, I can understand that.

Mr. COLLINS. Yes, we do plan—we do have and we shared—as a matter of fact, almost every bit of our planning documentation, and certainly in draft form, with this committee and they have treated it in that form, and we appreciate it and have appreciated their comments on it. Yes, in essence, that planning data is to be available as it has been in the past.

Mr. LEWIS. OK. Very good. As you know, the Energy Research and Advisory Board has issued a report on solar energy R&D needs. To what extent has DOE implemented the recommendations of ERAB?

Mr. COLLINS. Mr. Lewis, I'd like to defer to Dr. San Martin.

Dr. SAN MARTIN. Yes, sir. I'm very happy to be able to report that the budget and program that is being presented to the committee today is in very good accord with the ERAB solar panel report. I think many of us concluded that was a very good piece of work undertaken by the agency's advisory board, and it's one that we take very seriously and feel that it has contributed to the progress of these programs.

Mr. LEWIS. Do you feel that the DOE budget is consistent with ERAB's recommendations?

Dr. SAN MARTIN. Yes, sir.

Mr. LEWIS. Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Lewis. Mrs. Schneider?

Mrs. SCHNEIDER. Just to follow up on that question, I recall in previous hearings that we have had there had not been an acceptance of the ERAB report's recommendations by the Department of Energy. So are you saying that insofar as the conservation portion of ERAB's report is concerned that you have picked up on those recommendations?

Mr. COLLINS. I think that that's fair to say—that we have met with them, we have discussed those, and I will say this: When I appeared before the ERAB Board last, although our budget wasn't finalized totally, they had one question is all in one area.

Mrs. SCHNEIDER. That was it?

Mr. COLLINS. That was it.

Mrs. **Schneider**. Well, that's pretty terrific. You're definitely to be commended, then. I'm anxious to know, in your buildings and community systems program, which is an area that is often discussed here on this committee, there is the funding for the district heating and cooling system and also the urban waste to energy program, and I wonder if you could elaborate a little bit about the status of those two programs, in particular, and what kind of funding is included for each of those.

Mr. **Collins**. Mrs. Schneider, we're continuing on some of the projects with which many people are familiar, both in the Georgetown University area and beyond, and I think about 18 communities—but I've taken that off the top of the head—three of which of those communities, by the way, have gone beyond the research and actually instituted their own system. I would like to ask John Millhone, who is head of this, to elaborate further.

Mr. **Millhone**. In the area of district heating, the district heating activity would be one of the major efforts that would be covered in the $2 million appropriations as requested in fiscal year 1985.

Mrs. **Schneider**. What portion of that $2 million would be for district heating?

Mr. **Millhone**. About a million and a half would be district heating related.

Mrs. **Schneider**. OK. Thank you.

Mr. **Millhone**. Part of that effort, we also are intending to work with HUD to——

[Reporter interrupts to tell Mr. Millhone his microphone is not working.]

Mr. **Millhone**. OK. I'll speak up a bit. In this year we are also working with HUD on the possibility of developing some new feasibility study grants to follow up the kind of activity we did with HUD earlier where grants were given for preliminary feasibility studies to 28 communities. That has been extremely successful in that 10 of those 28 either have undertaken work or are currently completing the engineering studies to do that work, and we expect altogether $100 million in district heating investment to come out of those feasibility studies. We think that it is desirable to keep this kind of activity stimulated by providing some additional grants and have identified $200,000 in the fiscal year 1984 budget to be used for this purpose, with $400,000 anticipated out of the 1985 appropriation, if that $2 million is approved.

Mrs. **Schneider**. Just out of curiosity, are most of those 10 out of the 28 using systems that were in place, for example, back in the forties or thirties? Are they recycling old systems or are they feasibility proposals for the construction of new projects?

Mr. **Millhone**. Most of those are involved in new projects.

Mrs. **Schneider**. And most of them, I might guess, are in the Northeast and Midwest part of the country?

Mr. **Millhone**. Most of them are district heating rather than district heating and cooling. The cities involved are Baltimore, Provo, and Lawrence under construction. The marketing and financial studies are under way in New York; Lewiston, ME; Springfield, MA; Devils Lake, ND; Atlanta; Richmond; Holland, MI; Campbellsville, KY; and Columbus, OH.

Mrs. SCHNEIDER. OK.

Mr. MILLHONE. It seems to be Northeast, Northwest, some in the mid-continent area.

Mrs. SCHNEIDER. OK. And what about the whole area of urban waste to energy, how is the funding proposal there?

Mr. MILLHONE. The urban waste to energy activity has shifted from the buildings and community systems area that I'm responsible for over to the biomass area, where I think it's incorporated in continuing activity in that area.

Mrs. SCHNEIDER. I see.

Mr. MILLHONE. We haven't yet addressed the urban consortium question which you raised.

Mrs. SCHNEIDER. OK.

Mr. MILLHONE. There are no funds in the 1985 budget for the urban consortium. There we have a significant increase in technology transfer and plan on working with urban consortium along with other organizations to that extended technology transfer.

Mrs. SCHNEIDER. OK. I have a problem in that I have about 17,000 more questions, Mr. Chairman. Do I have time for one more?

Mr. FUQUA. Sure.

Mrs. SCHNEIDER. All right. You had mentioned technology transfer just now, and this is something that is incredibly frustrating to me insofar as we here as members of this committee have the opportunity to hear from either Government officials or from the private sector the phenomenal advancements that have been made in energy conservation technology, but yet I have factories and different kinds of plants up in the Northeast about to fold, and it's only through my taking this information from my committee that they are able to know that this exists. Now, granted, there are a lot of other things that we have to do with our energies, and I have not witnessed at all any kind of technology transfer program that is reaching the people. Now if we have this technology, what are we doing to get the word out and to get it implemented, and are there any not only information transfers, but are there any incentives that will encourage people to use these?

Mr. COLLINS. Well, Mrs. Schneider, I'm pleased that you've brought that up. There's a 500-percent increase in this fiscal year 1985 budget proposal before you. One of the reasons, many reasons is that it's certainly important. I know from personal experience in only 6 months in this position, I went to three States and they were heading down the track on projects which had failed in other States and they weren't aware of it. And I think it is a terrible waste. And, therefore, we are proposing a clearinghouse function in the DOE, certainly the fellowship program where we get State and local officials into our labs as well as private sector people who have been successful in these programs—for example, the shared savings and other incentives in conservation. And we think—Secretary Hodel and I think this is one of the most exciting and certainly productive things that we are doing. We also realize in some areas it's going to be good enough to get this down to the business level, but in some areas we may even have to go to the ultimate consumer. For example, to get residential conservation, we probably are going to have to get the ultimate consumer to ask that business person to incorporate those conservation advantages that we have learned about through the millions of dollars, billions of dollars, that we have put into research in the last 10 years in this area. We agree there is nothing more important, and there is probably not a sadder waste of public funds than when someone heads down the track where somebody's already been before.

Mrs. **Schneider**. Right. Well, my time has run out. I would be very interested if you could provide me with a follow-up on exactly how this clearinghouse will function. Tell us the toll-free phone numbers to call and all that sort of good thing. Thank you.

[Material referred to follows:]

As indicated, the clearinghouse function is being proposed; in other words, how it will operate is being defined. The current technology transfer initiative, which has been underway since last fall, has three main elements: (1) the development of a comprehensive program plan focused on the transfer of proven techniques and technologies pertaining to conservation and renewable resources, (2) a rational awards program to recognize and encourage transfer to innovations recommended by the States and (3) a new procedure in DOE to stimulate the suggestions by staff for effective ways to encourage technology transfer.

The clearing house function is one of the proposals in the draft plan in order to fill a widely recognized need for a mechanism to encourage routinely the awareness and practical understanding of demonstrated techniques and technologies among those who can benefit from their applications. Of course, we intend to make maximum use of existing systems such as the Department of Energy Technical Information Center, the Conservation and Renewable Energy Information and Referral Service, and the National Appropriate Technology Assistance Service. The hotline phone number for the Conservation and Renewable Energy Information and Referral Service is U.S.A. 800-523-2929 only Pennsylvania 800-462-4983. The hotline number for the National Appropriate Technology Assistance Service is 800-428-2525 (Montana: 800-428-1718).

Mrs. **Schneider**. Thank you, Mr. Chairman.

Mr. **Fuqua**. Thank you. Mr. Gregg.

Mr. **Gregg**. I'll yield my time to the gentlelady from Rhode Island, Mr. Chairman.

Mrs. **Schneider**. Thank you. I had another question that you raised, Mr. Collins, having to do with indoor air pollution. That had been part of the buildings and community systems program. And I was curious to know about the level of funding there; what kind of exchange exists with EPA, who is doing some of that study and exactly where you are in the proposal for the '85 budget with indoor air.

Mr. **Collins**. There has been an interrelationship there and it continues. I'd like to have Mr. Millhone elaborate on that, if he would, please.

Mr. **Millhone**. In the indoor area, the request for funds in fiscal year 1985 is $1.4 million compared with $1.3 million in fiscal year 1984. The Department of Energy, primarily to work at the Lawrence Berkeley Laboratory, has been involved in indoor air quality back into the midseventies, and I think that we have some of the expertise in that area that is now starting to be recognized as a result of the lengthy investment that we've made in that area. We feel as if our role in the indoor air quality area is primarily those areas that relate to energy conservation investment in buildings. However, we're concerned that the expertise that we have in this area be used by EPA as it takes the lead in developing a coordinated, interdepartmental national indoor air quality program. So we're working with the EPA in that direction.

Mrs. **Schneider**. I see, but you are focusing singly on one sector, and that sector would be in the building knowledge area?

Mr. **Millhone**. We feel as if our primary responsibility is in that area. We're not going to desert some of the broader activities that we've done in this area until it finds a home, and it should find a home with EPA.

Mrs. **Schneider**. OK. And the final thing I wanted to mention is something that appears to be controversial, although we're getting verbal communications of this; we don't have anything in writing yet. But, evidently, DOE has recommended no funds for the Energy Extension Program. The proposal is that the programs that are currently under the Energy Extension Service would now be funded out of the Petroleum Overcharge Restitution Fund. I'd just like to hear some comments on that, and then I'll give you some of my own. [Laughter.]

Mr. **Collins**. Well, Mrs. Schneider, we'll be up here on the Hill tomorrow to brief interested members and staff on our proposal, which is consistent with the numbers in the budget along this line, and basically it is to utilize that funding mechanism for certainly the weatherization program and the schools and hospitals program. And I did have a chance to address the chairman's comment earlier on the Energy Extension Service and the SECP, the State Energy Conservation Program, which would not be included in that proposal. I think the important thing for the recipients—and, of course, they're the important people in this whole process—is not whether it is a relatively unique legislative vehicle or something, but that they receive the benefits and are insured that they will receive them on a timely basis. And in this sense, we're very pleased that the fact of the matter is, if we fail under our legislative proposal to win the court cases or we do not get the judgments in time, they will actually be guaranteed against the General Fund for a period of 5 years. And this is very consistent with what the State energy directors told us in meetings last fall, that they wanted to see some sort of affirmation of the commitment of the administration to go with what has been a very constant commitment from the Congress in these two areas, so that they could feel assured that there will be continued funding in these areas. I think that this continuity is affirmed by that commitment.

Mrs. **Schneider**. Well, just to clarify, it's my understanding that the States have communicated, No. 1, that they would like to have that petroleum overcharge money, period, and, No. 2, perhaps on another day or under different circumstances, have also communicated the fact that they, too, would like to see the continuation of the Energy Extension Service programs. And I am saying this because it's my understanding that the State governments are not at all enthused about tying this mechanism to the guarantee of funds. And I just left a meeting a short while ago at which time Minnesota Gov. Rudy Perpich had been reporting on an energy conference that was held in his State, and they passed five resolutions, and one of those resolutions happens to say that the conference recommends that the States in the Northeast and Midwest support an increase in the Federal commitment to conservation and renewable resources and research. And then the fifth resolution says the conference opposes—and I underline "opposes"—the use of oil surcharge funds to supplement other Federal appropriations for any of these purposes. So I think that—and I've also been aware that the Council of Governors are talking among themselves, perhaps to spring their opposition on this proposal, also. But I think you ought to keep that in mind. And tomorrow we'll be looking forward as to whether or not the legal counsel from the general counsel's office has indicated that this is something that you can legally do, anyway. So we'll postpone that until tomorrow.

Mr. **Collins**. I appreciate that. If I may, Mr. Chairman——

Mr. **Fuqua**. Sure.

Mr. **Collins** [continuing]. Just a brief response. I'd like to say that, first of all, our first commitment is to take care of the injured parties where they can be identified. And then, beyond that, I will say that a great many people have expressed interest in these funds and a great many entities, and some more public than others. Some have expressed very privately that they would like to go—have these funds go into a general fund in a State or something else like this. We think that this is an opportunity for us to express our commitment to the people who are generally—who need this weatherization and low-income energy assistance for their heating bills, and I'm very pleased that it is being focused at these particular people because, like I say, we've had a multitude of suggestions where it could go, and this is a strong commitment by us along this line. It's consistent with what we—some directions that we have gotten from those in the energy and weatherization areas and low-income heating assistance areas, and we're very pleased by it. Thank you.

Mrs. **Schneider**. OK. Thank you very much.

Mr. **Fuqua**. Thank you. Mr. Ottinger?

Mr. **Ottinger**. We're having hearings this afternoon from 2 to 4. The National Governors Conference is appearing, and their first point is the governors oppose the administration's proposed legislation to replace regular appropriations for five major State energy programs with oil overcharge refund dollars. And we will be having outside groups as well. And I would hope that you could attend or, if you can't, at least you would have somebody there.

Mr. **Collins**. I'd be pleased to if I can.

Mr. **Ottinger**. I am very concerned that Secretary Hodel and the administration are merely giving lip service to conservation and solar and a new emphasis and are flimflamming the Congress, as indeed this administration has continuously, with respect to serious pursuit of these programs. Now I'm going to ask several questions. Because of the time limitation, if you would make note of them and address yourself to them. The first thing that concerns me is the President's proposed deferral of $10.077 million in fiscal year 1984 funds for conservation and some $10 million in solar. With respect to the conservation funds, those appear to be 1983 funds, and the failure to send up deferral or rescission appears to be an illegal impoundment. With respect to both the funds, considering you're operating under the tightest of budgets, I can't understand, if you're really serious in pursuing conservation and solar, why you would be asking to defer those funds at all. All the programs are clearly short, and it indicates to me a lack of seriousness with respect to the programs. Then there's this new device that has been invented, I guess by OMB, called deobligations, where funds which are deobligated will no longer go back to the accounts to be able to be spent for the programs for which they are intended but are to be impounded. And I wondered if there's a plan to send up deferrals and rescissions with respect to deobligated funds, why this is being done? Is it not, in reality, just an effort to try and cut back these programs even further? The third thing that I'd like you to address is that the DOE prepared a very good and thorough 5-year planning document for conservation research, and the 1985 budget request seems to ignore it completely. The funds that are requested are not in line at all with the recommendations of your own study. Why should that be? With respect to the solar and renewable energy research, there is a similar planning study. We have requested it and have been told we couldn't have it. I will move in my committee to subpoena it if we don't get it. What is the status of that, and is that going to be ignored as blithely as the conservation study? Lastly, in technology transfer, we're very concerned not only about the elimination of the Energy Extension Service, which has been one of the most useful devices—and it was one created in this committee by Congressman Thornton's initiative some time ago—but also the State energy conservation program. If you're going to be turning responsibilities back to the States, then why on earth are you trying to cripple the States in being able to pursue these programs, considering the fact the Government doesn't show much indication of interest? The State energy offices have already been eliminated in several States because of the lack of support, and that is a matter of serious concern. Those States are New Hampshire, Delaware, and Texas. I wonder if you could address yourself to that, and the degree to which your actions are going to match your words with respect to real support of energy and conservation—energy conservation and solar.

Mr. COLLINS. Mr. Chairman, should I just start down the list or——

Mr. OTTINGER. Yes, I'd like you to address yourself to the deferrals and why on earth——

Mr. COLLINS. Sure.

Mr. OTTINGER. With such short funds money is to be deferred, why you're going to try and eliminate funds from deobligations. I'd like to know how much those are expected to be, and then the transfer programs and the studies that have been made and haven't been followed.

Mr. COLLINS. First, I think that we—as I mentioned earlier in this committee, we're very pleased to have shared almost all of our planning documents with this committee or its staff, and continue to do that. However, when we—and we appreciate that they have been not represented as anything more than they are in many instances, and that's a draft. And some of the priorities have changed. And we are relatively close and pleased, as I said in my opening statement, Mr. Ottinger, that I think that we're about 200 percent of what we requested last year, and much closer in the one particular area you suggested, in the area of about 80 percent of that original draft plan. Second, I'm not familiar with the plan that we have not—in fact, I'm not familiar with anything at the Department that we haven't shared with the committee. Maybe on the solar I'd like to ask Dr. San Martin if he's familiar with that document.

Dr. San Martin. Mr. Chairman, I can only concur with Mr. Collins. I'm not aware of what document you're interested in that has not been made available to you.

Mr. Ottinger. Well, it is a 5-year planning document for solar and renewable energy research that was conducted in the same manner as the conservation document was. We're told that there is such a draft. When we asked for it, we were told it's still being reviewed and would not be made available to us——

Dr. San Martin. Mr. Chairman——

Mr. Ottinger [continuing]. By your liaison office.

Dr. San Martin. If I can attempt to address what I think the discussion might be, No. 1, in each of the technology programs, there either exists a well-reviewed and approved multiyear program plan or one in draft form in one stage of completion or another. And, obviously, you or members of your staff are welcome to copies of such. With regard to the type of management system that Secretary Hodel has implemented in the Department, he conducts a series of MBO meetings throughout the Department, and various activities have been targeted, scheduled in this particular MBO process. Conservation was fortunate and have completed their 5-year R&D plan and gone through the various scrutinies that take place in the Department. The renewable energy area is in the process of conducting that, working toward developing a strategy, not a program plan in the traditional sense, but developing a multiyear strategy. In fact, the first draft of that has not yet come to my office officially. I would of course sit down with Mr. Collins and desire to review the contents of that.

Mr. Ottinger. Well, this is the document which is the conservation R&D plan [holding up document]. We have gone through it. It seems to be very thorough. It does build on the studies that have been made previously by SERI and various outside groups with respect to conservation and follows very closely the kind of recommendations that were made by the ERAB review group. It is always of real concern that you have really good people study these things, including internal people in the Department; they come out with strong recommendations; and then I don't know whether it's OMB or whether it's the Department itself, but they don't pursue the programs that have tremendous paybacks and have been demonstrated to have tremendous paybacks. A lot of the building system stuff that you'll hear from Art Rosenfeld this afternoon have really remarkable paybacks in terms of energy savings, billions of dollars to consumers throughout the country in terms of saved oil and additional protection to the United States. You find these things; you say: "Yes, they're so, but we're going to ignore them."

Mr. Collins. I think, if I may, Mr. Ottinger, our response is that when the solar and renewables document gets into that same form that the conservation is, we'll be glad to share it with you. And I think that's generally been the Secretary's rule across the board, is to share anything——

Mr. Ottinger. I wonder, with the chairman's indulgence, if you could address yourself to deferrals and deobligations.

Mr. COLLINS. Fine, Mr. Chairman. On the deferral question, I am relatively new to this process, but I'm informed that that represents the amount of money that had not been expended. Certainly—I under—at the end of the fiscal year I understand this committee and other committees' concerns that at the start of last year and at the beginning of the fiscal year, and certainly maybe through the first couple of quarters, that money was not expended as expeditiously as this committee and others wanted to. It was not out in the research area. It is moving that way now, but I, of course, came onboard 3 months before the end of the fiscal year and this represents the amount that was outstanding at that time. Should I go through the rest?

Mr. OTTINGER. Yes.

Mr. COLLINS. On the deobligation, I want——

Mr. OTTINGER. Are the conservation deferrals of 1983 funds or of 1984 funds? We've gotten different answers from different persons in the Department?

Mr. COLLINS. John?

Mr. MILLHONE. It's my understanding that it is a carryover from 1983 into 1984, so that it is money that was initially appropriated in 1983 but was not spent and was available in fiscal year 1984.

Mr. OTTINGER. Then why are 1984 programs being held up, and isn't this an impoundment that is clearly illegal?

Mr. COLLINS. Mr. Chairman, I don't know the answer to that. I'd like to supply that for the record, if I may.

Mr. OTTINGER. Surely.

[Material referred to follows:]

FY 1984 deferrals for Conservation and Renewable Energy Programs were transmitted to the Congress on February 1, 1984. These deferrals include $10.1 million under the Energy Conservation Appropriation and $10.1 million under the Energy Supply Research and Development Appropriation.

The $10.1 million under Energy Conservation includes: $2.9 million from Buildings and Community Systems, $2.9 million from Industry, $2.8 million from Transportation, $0.5 million from Multi-Sector, and $1.0 million from State and Local.

The $10.1 million under the Energy Supply Research and Development Appropriations includes: $7.4 million for Solar, $0.6 million for Geothermal, $0.3 million for Hydropower, and $1.8 million for Electric Energy System and Energy Storage.

These deferrals reflected unobligated balances which exceeded the current obligational plans of the program. Therefore, the amounts were deferred under the provisions of the Congressional Budget and Impoundment Control Act of 1974 (P.L. 93-344), Sections 1012(a) and 1013(a). These funds will remain in a reserve account unless either House of Congress passes an impoundment resolution disapproving them. In the absence of such a resolution, the funds will be used to reduce the requirements for new budget authority in FY 1985.

Mr. COLLINS. On the—I think on the deobligation question, we're talking about funds and contracts that may be closed out, and I think that you may be referencing, to some degree, the management initiatives part of our budget. Along that line, we have a list of areas that we're going to pursue. It's new. I don't know if we will be as successful or even more successful than we think at the outset, but allow me to share some of these areas: Administrative organization management, where we hope to do some improved planning and control of organizational structures; administrative systems. We want to improve the automatic data processing within the Department. We think there would be a savings there; in the administrative processes, in the field structure. We want to work with the Government-owned and contractor-operated companies in becoming closer with our operations offices. We're putting in the payroll and personnel, for example, automated systems for that, where we think that there's some savings. In procurement, we plan to use increased use of contractor audit support, and cash management. We hope to make improvements in both billing and collecting. In financial systems, printing and publications—we hope to save some by using commercial facilities, and travel management as well.

Those are the categories which we hope, throughout the entire Department, to achieve these savings.

Mr. OTTINGER. But the savings will not be devoted to the programs for which they were authorized and appropriated?

Mr. COLLINS. I think that we don't have them assigned to programs per se, and they may come from entirely different parts of the Department of Energy. It's an overall departmental goal, and there may be areas where that's much more realizable than in ours.

For example, in travel management, although we can manage travel more, we have increased the travel budget alone, for example, in the area of conservation and renewable, so we can do more outreach and more technology transfers, so I don't think——

Mr. OTTINGER. These deobligations, to the extent that there are contracts and they get canceled for one reason or another, those funds will no longer be used for the purposes for which they were authorized and appropriated? It's the intention of the Department to use this device to reduce the funds available for the programs; is that correct?

Mr. COLLINS. Well, I think if we, for some reason—and there's certain areas where contracts are not realizable, and I think we even alluded to some earlier in the testimony here, that those will, under this program—that is administrationwide—I believe that is my understanding of that, but I'd like to say that management and administration is not my primary focus in the Department, and I certainly stand to be corrected on that and would like to provide correction if I'm incorrect on that. We're starting down the path on this, as you know, in reform 88 and other procedures that we have developed, mainly through coordination with the Office of Management and Budget, and we'll have to see how it works. I think it's something that we feel we should try, certainly, and make a best faith effort. On the other question on the EES and SECP, Mr. Ottinger, my notes here—you say that—I think I alluded earlier that some States have done some good work with those programs and some haven't. I think it's fair to say, and I think everyone would agree to that. We hope that our technology transfer initiatives, where I say we have a 500-percent increase, will be a more effective way to operate these programs. And I believe, Mr. Ottinger, that I have covered the major points that you made.

Mr. OTTINGER. I thank the chairman for his indulgence. And I would indicate that I think the answers are just totally inadequate today. It's your job to pursue these programs and to fight for them, rather than to preside over their demise and the use of these various new techniques to accomplish their demise. Thank you.

Mr. **Fuqua**. Thank you, Mr. Ottinger. And thank you, Mr. Collins, and your associates for being here this morning. There may be some written questions that some of the members may wish to submit. Thank you very much for being here.

Mr. **Collins**. Thank you very much, Mr. Chairman.

Mr. **Fuqua**. Without objection, following my opening comments I would like to submit a statement by Mr. Winn for the record. Our next panel would be Dr. Paul Berdahl for the Lawrence Berkeley Lab; Peter Johnson, Office of Technology Assessment; and Dr. Sidney I. Firstman, president of Biomass Energy Research Association. Dr. Berdahl, we're happy to welcome you this morning. We would be pleased for your statement. I might add that if any of you gentlemen wish to make your statements part of the record and summarize, we would be delighted to proceed in that fashion, and the entire statement will be made part of the record.

## STATEMENT OF DR. PAUL BERDAHL, SOLAR RADIATION DIVISION, AMERICAN SOLAR ENERGY SOCIETY, BOULDER, CO, AND LAWRENCE BERKELEY LABORATORY, BERKELEY, CA

Dr. **Berdahl**. Yes, Mr. Chairman, that's what I'll do.

Mr. **Fuqua**. Thank you very much.

Dr. **Berdahl**. I'm Paul Berdahl, a research scientist at Lawrence Berkeley Laboratory in California. I'm appearing before you today on behalf of the American Solar Energy Society and its Solar Radiation Division.

We in the Solar Energy Society were very pleased to learn that your committee was investigating the problems with Federal solar resource assessment activities. To assist with this effort, at the request of Chairman Fuqua, I convened a meeting of interested scientists in Baltimore this past November. These scientists had gathered for a technical conference on radiative transfer in the atmosphere. The purpose of the meeting was to develop a consensus on the form and content which the U.S. solar resource assessment program should have and to recommend actions to put such a program in place.

We were able to come to general agreement, and our recommendations are contained in the written statement I conveyed to you today. With your permission, I will summarize the statement.

Why is a solar resource assessment program necessary? Thanks to the current overcapacity of world petroleum production and a high level of conservation, the Unitesd States has a temporary breathing space to prepare for the day when our domestic supplies will be exhausted and world oil becomes increasingly costly. However, there is general agreement that by the turn of the century, if not before, major new energy supplies will be required. Solar energy technology, already supplying some of the Nation's energy, can make a major contribution. Solar capacity will continue to come online as technological innovations push costs down, and this process will accelerate if other real energy prices rise further.

To assist in the development of society's solar option, a Federal solar resource assessment program is required. The goal of this program should be the provision of the basic solar resource information needed to plan, design, and operate various types of solar systems. One needs to know the magnitude and characteristics of the energy flux from the sun as received at the Earth's surface. Clearly, this information is essential if estimates of solar energy production are to be reliable. If you don't know what goes into a solar device, you certainly can't predict what comes out. The solar information developed by this program need not have excessive precision, but it must be comprehensive; that is, useful for all types of solar systems, and it must be reliable.

The type of solar data required depends on the application. Flat plate collectors for the heating of water utilize the total radiation received by a tilted surface, both the part received directly from the Sun, called the direct radiation, and the part received from the clouds and blue sky, called the diffuse radiation. Solar systems which focus radiation can achieve higher temperatures but utilize only the direct radiation, since the diffuse radiation cannot be focused. Photovoltaic cells, the solid state devices which produce electricity, utilize the different colors or spectral components of the radiation with different efficiencies. Thus, one needs to know the spectral distribution of the radiation. Each technology has its own particular needs for solar resource information, and it must be anticipated that new applications will appear with additional new requirements as the result of industrial innovations. Thus, there are many different types of solar radiation information needed, and one would like to have this information for all locations in the United States, and even for other countries. The necessary program of direct measurements of a few types of information at a few sites cannot do the whole job. We also need a program of applied research which can provide techniques for estimating unmeasured solar quantities.

As an aside, I would like to point out that solar radiation data have many important applications not directly related to energy production. The solar radiant intensity is a basic quantity of our environment similar to air temperature, rainfall, wind speed, and so forth. It is studied in climatology both because it is an element of climate, and also, it influences climate. Hydrologists use solar radiation data in their estimation of evaporation from lakes and reservoirs. Researchers studying the atmospheric photochemistry of air pollutants also use solar data. A number of further applications of the data in biology and agriculture stem from the solar-driven phenomenon of photosynthesis. The diversity of the applications of solar radiation data illustrates the need to have a well-rounded and flexible national solar resource assessment program.

For the sake of brevity, I will not delve into the history of the solar radiation measurements and analysis in the United States. Real progress has been made, but much more remains to be done. A continuing program of measurements and a continuing program of applied research to ensure the utility of the data are needed. While the elements of a solar resource assessment program were put into place in the 1970's, there is no real program today. Therefore, the following actions are recommended:

First, the national 38-station Solar Radiation Monitoring Network must be refurbished and operated so that eventually long-term solar radiation records are available with 5 percent measurement accuracy. This work should be performed by NOAA at a cost of $900,000 in fiscal 1985 and be continued indefinitely.

I realize that this subcommittee does not oversee NOAA, but this recommendation is certainly a necessary part of the overall program.

Second, the former DOE program entitled, "Solar Energy Meteorological Research and Training Sites," at eight universities, should be restored. Two new sites should be added, one located in a polluted urban environment and one in the desert Southwest. The purpose of these sophisticated research stations is to make extensive solar radiation measurements and perform related research. This work should be funded by DOE at a level of $1.5 million in fiscal 1985 and $1.1 million per year thereafter.

Third, additional solar resource research is further required to make measured solar radiation data fully useful to people who plan, design, and operate solar systems. This research requires the development of techniques for estimating solar radiation at locations with no measuring stations, techniques for estimating the spectral distribution of the radiation for photovoltaics applications, and so forth. The funding level for this work should be $900,000 in fiscal 1985. Thus, our estimate of the total new funding required for DOE's portion of the solar resource assessment program is $2.4 million for fiscal 1985. To assist the Department of Energy with the formulation of a multiyear plan for solar resource assessment, we recommend holding a workshop. In addition to reviewing the existing solar resource program at the time of the workshop, participants should evaluate the need for program expansion. In conclusion, most of the elements of the National Solar Resource Assessment Program were put into place in the 1970's with funding from the various solar technology programs. During the early part of this decade, basically for budgetary reasons, solar resource assessment activities were virtually eliminated. As a consequence, useful solar radiation data are not being collected by the Federal Government, and the data that have been collected cannot be fully utilized because related research analyses are no longer pursued. It is recommended that funding for the solar resource assessment program be restored and that the funding be explicitly identified with line items in the budget for DOE and NOAA. The results of this program, sustained over a period of years, will be better quantitative knowledge and better qualitative understanding of our abundant solar resources.

[The prepared statement of Dr. Paul Berdahl follows:]

# Statement for the House Science and Technology Committee:

# Solar Resource Assessment Program for the United States

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and

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## I. Origin of this Statement

A group of scientists active in solar radiation research and staff members of the House Science and Technology Committee met on November 2, 1983, in Baltimore during the Fifth Conference on Atmospheric Radiation sponsored by the Committee on Radiation of the American Meteorological Society (AMS) and co-sponsored by the Solar Radiation Division of the American Solar Energy Society (ASES). The group included scientists active in solar energy applications, solar radiation climatology, and solar radiation measurements from universities, government research laboratories, and private industry. The purpose of the meeting was to develop a consensus on the form which the National Solar Resource Assessment Program should have, and to convey this information to the House Science and Technology Committee chaired by Congressman Don Fuqua.

The statement was drafted by a subgroup consisting primarily of members of the Solar Radiation Division of ASES, and circulated twice for comments to all the meeting attendees. A substantial consensus was thus obtained. (This consensus does not, of course, represent official policy of the AMS or ASES.)

Section II contains a summary statement of the current serious problem with solar resource assessment in the United States, followed in section III by a general description of what is needed and why. Section IV contains specific recommendations for action by the federal government. The statement concludes with a section (V) on commonly asked questions concerning solar resource assessment, with essay answers.

## II. Summary Statement of the Problem

In the early 1970's, as a response to the nation's acute need to develop domestic energy resources, a federally funded solar energy research and development program was begun. The primary mission of the program is to develop solar technologies for the economical conversion of sunlight to energy forms such as heat and electricity. As a part of this program, it was necessary to gather better information on the solar resource.

As a first step, 25 years worth of solar radiation data taken by a National Weather Service (NWS) network were rehabilitated and made available through the SOLMET tapes. A new national solar data network with 38 stations was developed and put into operation by NOAA with initial support from DOE. The network was designed to provide long-term measurements of a few basic solar parameters. Another important initiative involved eight universities which were chosen as Solar Energy Meteorological Research and Training Sites (SEMRTS) to provide more detailed but reasonably standard measurements of the solar resource and to provide training for both students and professionals. Finally, an aggressive research program developed new and specialized instrumentation, made unique measurements not available through the network or the SEMRTS, developed models of solar transmission through the atmosphere, and developed techniques to make the solar data directly usable by each solar technology. This research program involved universities, industries, the Solar Energy Research Institute, and other national laboratories.

This solar resource assessment activity was not independent but was supported by funds appropriated for the solar conversion technology programs. As the consequence of the cutbacks in federal funding for solar energy since fiscal year 1981, solar resource assessment has been nearly eliminated. The new solar radiation monitoring network remains in limited operation, but with such a meager level of support that it is unlikely that the network will produce much usable data. The SEMRTS funding ended in fiscal year 1982 and the skilled personnel and extensive equipment are starting to be dispersed. The once vigorous research effort managed by SERI has been reduced to a small in-house effort. Specialized instruments are going unused, accumulated data remains unanalyzed, and many of the efforts to provide the data in usable forms to the solar technologies have ceased.

Solar resource assessment is at a cross-roads. Without an increase in federal support most of the substantial federal investment to date in equipment, data, methods, and skilled personnel will be lost. A renewed national effort can prevent much of this loss and then proceed to provide the additional data and methods needed by present and future solar technologies. There is, however, a sense of urgency. Without funds in fiscal year 1984 the present SEMRTS will probably be lost. Enhanced funding is needed by 1985 if the investment in the new network and the research program is to be recovered.

## III. The Need for Solar Resource Assessment

Thanks to the current overcapacity of world petroleum production and a high level of conservation, the U.S. has a temporary breathing space to prepare for the day when our domestic supplies will be exhausted and world oil becomes increasingly costly. However, there is general agreement that by the turn of the century, if not before, major new energy supplies will be required. Solar energy technology, already supplying some of the nation's energy, can make a major contribution. Solar capacity will continue to come on-line as technological innovations push costs down, and will accelerate if other real energy prices rise further.

To assist in the development of society's solar option, a federal solar resource assessment program is required. The goal of this program should be the provision of the basic solar resource information needed to plan, design, and operate various types of solar systems. The solar information developed need not have excessive precision, but it must be comprehensive---useful for all types of solar systems---and it must be reliable.

The energy-related need for solar resource information stems from the requirement to know the available input energy to various types of solar energy systems. The type of solar data required depends on the application. Flat plate collectors for water heating utilize the total radiation received by a tilted surface, both direct (from the sun) and diffuse (from clouds and blue sky). Concentrating (focusing) solar collectors achieve higher temperatures but utilize direct radiation only, since the diffuse radiation cannot be focused. Photovoltaic cells, the solid-state devices which produce electricity directly, utilize the different spectral components (colors) of the radiation with different efficiencies, and thus require a knowledge of the spectral distribution of the radiation. Knowledge of short-term fluctuations and the time distribution of the solar intensity is of particular importance for solar electric applications. Each technology has its own particular needs for solar resource information, and it must be anticipated that new applications will appear, with additional new requirements, as the result of industrial innovations.

The many types of solar resource information required and the fact that one would like to have this information for all locations in the U.S. and even in other countries, means that direct measurement of solar radiation at a number of sites in the United States should be supplemented by a broadly-based program of solar radiation research. This is the rationale for the current recommendations which consist of strengthening the basic solar monitoring network and improving the research and analysis effort in the country.

The collection and analysis of solar radiation data has many important applications not directly related to energy production. The solar radiant intensity (insolation at the earth's surface) is a fundamental quantity of our environment, similar to air temperature, rainfall, wind speed, etc. In climatology, the solar flux at the earth's surface is an important component of the earth's heat balance, which is needed in calculations of the response of our climate to perturbations such as volcanic eruptions and the $CO_2$ increase Satellite estimates of surface insolation (radiation) require "ground truth" measurements to determine their accuracy. Researchers studying the atmospheric photo-chemistry of air pollutants also utilize insolation data. A number of applications of the data in biology and agriculture stem from the solar-driven phenomenon of photosynthesis. Hydrologists use solar radiation data in their estimation of evaporation from lakes, reservoirs, etc. The diversity of the applications of solar radiation data illustrates the need to have a well rounded and flexible national solar resource assessment program.

## IV. Recommended Solar Resource Assessment Program Components

### A. National Solar Radiation Monitoring Network and Associated Research (NOAA)

The current 38-station National Solar Radiation Monitoring Network operated by NOAA requires extensive refurbishment to ensure the eventual availability of 10 year minimum data sets with 5% measurement accuracy. We recommend the following actions:

- Install new automatic trackers for pyrheliometers
- Upgrade data logging instrumentation with reliable modern equipment
- Replace damaged sensors
- Continue and improve instrumentation calibration procedures
- Automate all possible data quality control procedures to reduce costs. Some routine manual data inspection is nevertheless required.
- Inspect measurement stations periodically
- Provide observers with training
- Publish the data in summary form

In addition to these primarily remedial measures, the question of the overall adequacy of the existing network should be readdressed by a workshop or similar mechanism. Issues to be addressed include the proper number of measurement sites, the types of solar radiation measurements to be made, and the role of satellite measurements.

Solar resource research associated with the National Monitoring Network should be pursued to enhance the utility of the data. Two examples of appropriate associated research tasks are (i) Investigation of long-term trends in solar radiation data, using network data as well as other sources (ii) Improvement of solar radiation forecasting skills, using network data to evaluate forecasts. A major benefit of this research is that it will help insure that the network provides very high quality data, by subjecting the data to rigorous scrutiny. This work should be coordinated with both climate research within NOAA and solar resource work funded by DOE.

### B. Solar Resource Assessment Research Program and Associated Monitoring (DOE)

This research program for resource assessment is required to bridge the gap between the availability of a few types of solar measurements at a few sites and the requirements for many types of solar radiation information at numerous sites. Thus, the emphasis of the research is on (i) the development of interpolation techniques to provide estimated solar radiation values at locations with no measurements and upon (ii) the development of models which can be used to estimate input solar radiation values for differing types of solar systems based on available solar radiation and weather data. The role of solar radiation monitoring (i.e., measurements) in the research program is to provide the data upon which interpolation techniques and models can be based. Often, specialized instruments and measurements are required.

Since the focus of this research is on solar technologies, the Department of Energy should be the lead agency. The Solar Energy Research Institute (SERI) should continue to serve as technical manager. In addition to the participation by universities (as outlined in part below), it is expected that the research program will involve groups from NOAA, SERI, other national laboratories, and private industry.

## 1. University Research and Training Sites

The former DOE program entitled Solar Energy Meteorological Research and Training Sites (SEMRTS), at 8 universities, has produced significant contributions to the characterization and quantification of the solar resource. This program should be restored. These sophisticated research stations have provided extensive solar radiation data sets which are very accurate and remarkable in that detailed components (spectral, angular, temporal) of the solar radiation were measured over a period of years. Related atmospheric parameters such as cloud cover, turbidity, and water vapor were also measured. The research analyses performed by these universities with their data have led to a clearer understanding of the characteristics of the solar resource. An associated benefit is the training of graduate and undergraduate students in solar measurements, climatology, and applications. Training has also been provided to solar data station operators, solar technologists, engineers, architects, and many businesses.

The data from the SEMRTS program has also been used directly for the design of solar systems. For example, data from one site was used to develop a solar passive system in Albany, New York, which won the Corning National Energy Conservation Award for an architectural and engineering firm.

In addition to the restoration of the former SEMRTS program, a recognized limitation of this program should be corrected. Two new SEMRT sites should be chosen, one in the desert southwest, and one in a polluted urban environment.

The recommendation for the restoration of the SEMRTS program does not mean that the same universities should be supported in the future as in the past; this decision should be left to DOE management. However, if funding is to be restored to particular universities, interim funding is required in FY 84 to maintain past investments in equipment and specialized personnel.

## 2. Solar Resource Assessment Research

This category contains those research areas pertaining to interpolation or modeling which require resources beyond those available to the university SEMRT sites. Four research areas are identified in which work should be pursued in fiscal 1985:

(a) Daylighting resource modeling techniques should be developed for estimating the luminous (visible) sunlight incident on the external surfaces of buildings, based on available solar and weather data. This information is needed to design buildings in which sunlight can partially replace electric light.

(b) Photovoltaic resource modeling techniques should be improved for estimating the portion of the solar flux which can be converted to useful electricity by various types of photovoltaic solar cells. This information is needed for the design of photovoltaic solar systems and to guide the development of photovoltaic cells optimized for performance in natural sunlight.

(c) Mesoscale-interpolation techniques should be developed. When solar radiation values are needed for system design or system feasibility evaluation, the numerical values used must be estimated based on measurements at other sites. The state of the art in interpolation is primitive, and should be improved to yield data with better accuracy and reliability. Of particular importance is obtaining a better understanding of interpolation near seacoasts, lakes, and mountain ranges, where average solar radiation values can vary greatly from one location to another.

(d) Analyze and publish existing solar radiation data. The best readily available national data summaries end with data from 1975, and contain no measured (only estimated) direct radiation values. Data collected between 1977 and the present from the national network, and data taken during the same period with specialized instruments or under special conditions are not generally available. These data should be further edited, scrutinized for possible systematic errors, and incorporated into tables, maps of monthly average solar radiation values, and figures as appropriate.

A fifth activity which should be pursued in fiscal 1985 is a workshop[*] or similar mechanism to assist DOE with the setting of research priorities and research plans for a multiyear period. In addition to representatives from DOE and NOAA, participation should be sought from professional societies and trade groups, from solar industries, and from utilities.

In addition to reviewing the existing solar resource research program at the time of the workshop, participants should evaluate the need for program expansion. Examples of issues which should be addressed are: Is there a need for the development of improved solar radiation instrumentation? Should existing computer codes for radiative transfer in the atmosphere be adapted or improved for solar resource assessment purposes? Which solar technologies have important unmet needs for solar resource information?

### C. Estimates of Required Funding

#### 1. Solar Radiation Monitoring Network (NOAA)

| | | |
|---|---|---|
| New equipment | | $200K |
| Installation | | 75K |
| Maintenance, data quality control, summary publication, etc. | | 450K/y |
| Calibration center | - | already funded |
| Associated research | | 150K/y |

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[*] This workshop could be combined with the workshop addressing the number and type of monitoring stations.

2. Solar Resource Assessment Research Program (DOE)

(a) Solar Energy Meteorological Research and Training Sites (DOE/SERI)

| | |
|---|---|
| Commission two new sites (urban and southwestern) | $400K |
| Continuing funding for a total of 8 to 10 SEMRT sites | 1000K/y |
| (FY 1984 expenditure of 300K highly desirable to avoid loss of benefits from prior investment.) | |
| Technical monitoring and coordination | $40K + $100K/y |

(b) Solar Resource Assessment Research

| | |
|---|---|
| Development of solar radiation models | $500K/y |
| Interpolation improvement | $300K/y |
| Update existing data | $75K |
| Workshop (multi-year planning) | $15K |

### D. The Need for Line-Item Appropriations

To reiterate from the earlier Statement of the Problem, the current unsatisfactory situation has arisen because the Solar Resource Assessment effort was originally supported from the funds appropriated to the various solar technology programs: with the cutbacks in federal funding for solar this support was nearly eliminated. The long-term nature of solar resource assessment requires a reasonably stable level of support. As indicated by the budget figures suggested above, this level is quite modest as compared to the overall federal support for solar technologies. The need for stable support is best met by having direct appropriations (line-items) in the federal budget. The suggestion is that there be two line-items, one for NOAA to carry out the above activities associated with the Solar Radiation Monitoring Network, and a second for DOE to carry out the research program.

It should be recognized that the suggested budgets may not be adequate to handle all of the needs of the solar technologies; it may be necessary for the individual technologies to fund additional specialized work.

## V. Some Common Questions Concerning The Need For Solar Resource Assessment For Solar Energy Applications

Questions are often raised concerning the need for a federally supported solar resource assessment program. Many of these questions are addressed here.

## Why do we need solar resource data?

This topic was covered in Section III. For completeness and emphasis we add a few additional comments. Solar energy conversion systems, whether flat plate collectors, concentrating collectors, photovoltaic cells, or living plants, convert a fraction of the available solar radiation to usable energy in some other form (heat, electricity, or chemicals). A knowledge of the solar resource is needed to predict the performance (how much usable energy will be produced?) and the cost (will the usable energy be economical?). A manufacturer or designer of solar systems will be interested in the solar resource for a region or the entire country in order to assess the market potential of the system. A building owner, public utility, or other potential purchaser of a system will be interested in the local resource in order to judge the economic value of the system.

A lack of data, or a perception that the data are inadequate, gives rise to an uncertainty in the expected performance and cost of a system; an uncertainty that will usually lead to a hesitancy on the part of both the potential marketer and the potential purchaser. Data that are thought to be accurate but which substantially underestimate the solar resource will deter the construction of solar systems because their predicted performance will appear to be too low and their predicted cost too high. Conversely, overestimated solar data will lead to overly optimistic expectations and to the purchase of systems that turn out to be uneconomical. Clearly the interests of the supplier and purchaser of solar systems are best served by having accurate solar data. From a national perspective, the proper allocation by market forces of scarce capital and material resources among competing technologies requires a knowledge of the solar resource as well as many other factors.

## How accurate do the data need to be?

For many applications the predictions of performance and economics are only moderately sensitive to errors in the solar data. Reasonable goals for a national data base are 1) to obtain data with 5% accuracy at ground-based solar data stations, and 2) to be able to estimate the solar resource anywhere in the country with 10% accuracy. The first goal can be achieved by a combination of modern instruments, periodic calibration and maintenance, and careful data processing. The second goal can in principal be achieved by developing methods of interpolating between stations using, for example, satellite measurements of cloud cover.

There are applications that require more accurate measurements. For example, adequate testing of an operating solar system or device (such as a flat plate collector) requires an accuracy that often approaches or exceeds the capabilities of presently available instruments. Evaluation of a candidate site for a large system, such as a central receiver, will generally require more accurate measurements than are necessary for the national network.

Aren't the existing data good enough?

The rehabilitation of the data from the old NWS network was in many ways a heroic effort to provide long-term (25 years) data for many locations; the data could not have been obtained in any other way. As important as these data are, they are of limited value or even of no value for many solar applications. The instruments that took the bulk of the data, so-called "lightbulb" pyranometers designed in the 1920's, are now known to be rather inaccurate under the best of conditions and certainly inferior to modern instruments. The data were collected over a long period of time during which the calibration of the instruments deteriorated. Because of the deterioration of the instruments, the normal calibrations had to be disregarded and a mathematical model used to provide an approximate calibration based on data taken during clear sky conditions. The overall accuracy is not really known, and will vary from location to location. The errors undoubtedly exceed the 5% goal and there are indications that in some cases the data may be in error by 20%. Further, the pyranometer measures the solar radiation incident on the horizontal surface. This measurement is most relevant to flat plate collectors. The SOLMET data base does not include measurements of the direct solar radiation as needed for applications involving concentrating collectors. Rather, SOLMET contains values estimated using a model. These calculated values must be regarded with skepticism at present. Information on the spectral composition of the sunlight, needed for photovoltaic applications, is also not available from the SOLMET analysis.

Why do we need many years of data?

Solar energy systems represent a sizable capital investment. Most solar energy systems will only be economical if they last for 10, 15 or more years. To accurately predict the performance and economics over such a time period requires a reasonably accurate knowledge of the average solar radiation that can be expected over that period. Because of the year-to-year fluctuations in the weather, a year or even a few years of data will be a poor predictor of the average value of solar radiation. For most locations five years is a marginal period of time over which to establish a meaningful average value. Ten or more years is desirable.

Another reason we need many years of data (and analysis of that data) is that solar system designers require statistical information which must be based on long records.. For example, they need to know how much energy can be produced in an unusually cloudy year. Another example, of great importance to electric utilities interested in investing in solar power plants, is the need to know the probability that the solar plant can operate during periods of peak electricity demand.

There are a couple of other points that need to be made concerning long-term data. The first is that any institution (whether or not it is the federal government) that starts a solar data network should be committed to continuing support for a many-year period. Rapid starts and stops of funding are very counterproductive. The other point is that if we envision a growing solar industry, especially over the next decade, then we need to start now in order to have adequate data five or ten years from now.

Given the natural year-to-year fluctuations in the solar resource, why do the measurements need to be accurate?

The goal is to obtain data for a sufficient length of time to average out the year-to-year weather-caused variations. For the most part, errors in the data resulting from inaccurate instruments or data processing problems will not average out and will affect the accuracy of the long-term average. For example, if the calibration of an instrument is off by 10%, then the long-term average will be in error by at least 10%.

Since the future cost of oil and other energy sources is uncertain, why do we need accurate solar data?

Certainly in most economic analyses the predicted cost of a solar system is compared to the uncertain future cost of conventional energy sources. However, economics aside, you would like to be able to accurately predict the performance of the system, that is, the amount of usable energy that will be provided, and for that purpose accurate solar data are needed. Further, of the various uncertainties (solar resource, future cost of fossil fuel, interest rates, etc.) the solar resource is the only one that is amenable to physical measurement. A reasonable goal is to reduce the uncertainty in the solar resource well below the others.

Why is federal support needed?

Measuring the long-term solar resource is similar to measuring long-term weather parameters such as rainfall. The nation is best served if the basic data are available to everyone (i.e., not proprietary) and if everyone is using the same common data. Further, the solar industry consists of a large number of small companies, many of which are struggling to survive. None of them have the resources to start a solar data network or to maintain a network for the necessary period of 10 or more years.

Solar resource assessment is a clear-cut case where a federal activity can benefit American industry without being in competition with that industry.

Is the present 38 station NWS solar network big enough?

It is certainly the case that many areas of the country, including some major urban areas, are quite distant from a solar data station. The number of stations in the network is admittedly somewhat arbitrary, but to cover all the populated areas and all the variations in climate would require hundreds or even thousands of stations and would be prohibitively expensive. What is needed is a way of interpolating between stations. In the case of the SOLMET data from the old network correlations between the pyranometer measurements and cloud cover were developed, and then used to roughly estimate the solar resource at some 220 locations that had cloud cover data but not solar data. A promising variation of this approach is to use measurements from satellites.

An alternative approach is to support the concept of regional networks. Regional networks, such as the Pacific Gas & Electric network in northern California and the University of Oregon network in the Pacific Northwest can provide detailed coverage and high quality data at a large number of sites, thereby greatly enhancing the value of the NOAA stations. Regional data is of timely importance in addressing research and analysis topics associated with a particular geographical (and climatic) area.

### Why not just use satellite measurements?

Satellites provide several measures of cloud cover, and a model must be constructed that relates the satellite observation to the solar radiation received at the earth's surface. Such models require that the satellite measurements be compared to ground-based ones. The network can supply these "ground-truth" measurements. It remains an open question as to whether 38 stations are sufficient for ground-truth purposes, whether more stations are needed, or whether the number can be reduced. Only additional research can answer this question.

Another point is that, so far, the satellite measurements are only good estimators of the solar radiation received on a horizontal surface. (Even these estimates are somewhat inaccurate during overcast conditions.) The satellites have not yet been used to yield accurate estimates of the direct solar radiation as needed by concentrating collectors.

### Why do we need a research program in addition to a solar data network?

The situation in the weather/climate area provides a good analogy. The nation has a substantial research effort devoted to improving weather predictions and understanding the climate - the research is necessary in order to make both the ground and satellite measurements useful. In the case of the solar resource the research makes the solar data useful to those involved in developing solar energy conversion technologies. There are several critical roles for research.

The first has to do with the solar parameters that are needed for calculations of the performance and economics of solar energy systems. The old NWS network provided only one solar parameter, the radiation incident on a horizontal surface as measured by a pyranometer. The new (1977) network would provide essentially two solar parameters, the pyranometer measurement and the direct solar radiation as measured by a pyrheliometer. Actual applications of the data to solar energy systems can seldom use these parameters directly. Flat plate collectors are usually tilted towards the south and thus need the value of the solar radiation incident on the tilted surface. Concentrating systems have an amount of solar radiation available to them that is only approximated by the pyrheliometer measurement. Photovoltaic applications require spectral information. It would be impractical and inordinately expensive to measure all the needed parameters at the regular network stations. Also, in many cases the necessary instrumentation is too complicated or requires too much operator involvement to be suitable for a network station. One role of the research is then to develop methods of transforming the standard network measurements so that they are applicable to the solar systems. Often this involves measuring many parameters (or specialized parameters) at one or a few sites and for relatively short periods of time. For example, tilted pyranometer measurements have been the basis for developing methods of transforming horizontal surface data to the (tilted) surface of a flat plate collector.

A second role for research is understanding the spatial variations in the solar resource. One example has already been mentioned; the potential role of satellite measurements for interpolating between ground stations. There are a number of other such questions. For example, most solar data stations are at airports, which are usually in open areas and deliberately chosen to have favorable conditions such as low wind speeds. How applicable are these measurements to urban areas where many solar systems will be installed? To what extent do air pollution and other urban atmospheric disturbances (like the urban heat island effect) alter the solar resource?

A third role for research has to do with variations in the solar resource with respect to time. Necessarily, solar measurements from the past are used to predict the resource for future solar applications. For example, solar data from the past ten years might be used to predict the performance of a candidate solar system over a projected 20 year life time. Will the average solar radiation value for the next 20 years be the same as for the past ten? This is a very difficult question to answer because it involves the impact (on the solar resource) of climate change. There is already a substantial national research program on climate change, and a modest additional effort should be adequate to study the impact on the solar resource. On a shorter time scale there is the question of to what extent solar radiation can be forecast like the weather, and if there is, is there an economic value to having such forecasts?

A fourth role, which is in support of the other three, is the development of advanced instrumentation and the improvement and application of atmospheric models. In the area of instrumentation, for example, a more accurate pyranometer (e.g. ± 0.5%) could greatly help in such tasks as solar collector testing, calibration of the pyranometers used in the network, and developing methods of calculating the radiation on tilted surfaces. Simpler instrumentation than is currently available is needed in the areas of spectral measurements for photovoltaic applications and detailed measurements of the sun and nearby sky for concentrating collectors. In the case of the atmospheric models, many of the above research questions are best addressed through an understanding of the basic scattering and absorption processes in the atmosphere that attenuate the solar radiation. Existing atmospheric models have proved extremely useful, but they need continuing improvement and updating.

Mr. FUQUA. Thank you very much. Mr. Johnson?

## STATEMENT OF PETER JOHNSON, DIRECTOR, OFFICE OF TECHNOLOGY ASSESSMENT'S STUDY OF OCEAN THERMAL ENERGY CONVERSION SYSTEMS

Mr. JOHNSON. Yes. Thank you.

Mr. Chairman, my name is Peter Johnson, and I have directed various studies of ocean thermal energy conversion at the Office of Technology Assessment.

Thank you for the opportunity to appear before this subcommittee today on behalf of the OTA and to discuss two things: first, our recent staff paper which reviewed the status of OTEC development and, second, the results of an OTEC workshop which was cosponsored by OTA and your committee.

The OTA staff paper, which is titled, "Review of Ocean Thermal Energy Systems," was published in January this year and was prepared at the request of your committee. We were able to prepare this review with a rather modest level of staff effort because we had conducted two previous studies of OTEC, in 1978 and 1980.

The most recent work was undertaken with particular attention to alternative technical paths for the OTEC concept, to current evaluation of OTEC economic feasibility, and to the question of future markets for OTEC products. We also did some evaluation of the present DOE OTEC program to determine whether clear goals have been set and whether a rational approach to meet those goals is in place.

As you know, OTEC is a solar thermal energy converter, tapping the energy resource created by the temperature differences of solar-heated surface ocean water and cooled subsurface ocean waters. Numerous OTEC concepts have been proposed which range from shore-mounted plants to moored or drifting offshore plants, and the sizes that have been proposed vary from plants producing a few hundred kilowatts to those generating hundreds of megawatts or hundreds of thousands of kilowatts.

Two basic OTEC techniques have also received quite a bit of investigation: the so-called closed and open cycles. Also, while electricity has generally been considered primary OTEC product, secondary products such as ammonia or methanol have also received considerable attention, especially for moored or drifting plants located in remote tropical ocean areas.

In the latter case, the electricity produced by the plant is used to produce hydrogen by electrolysis of water. The hydrogen, in turn, is used to synthetically produce methanol or ammonia. To produce methanol, a source of carbon is also needed and coal is considered the primary candidate.

The U.S. Department of Energy and its predecessor, ERDA, has funded an OTEC program since 1975, by expanding the research effort which was initiated by the National Science Foundation in 1972. By September 1983, over $200 million had been spent on federally-funded OTEC development. The expenditures and activity peaked in 1980 and have decreased since then. As a result of a considerable study of concepts and testing of components, early design phases of a 40,000 kilowatt, shore-based pilot plant, to be sited in

Hawaii, have been completed. Since 1980, Federal policy toward OTEC has concentrated on research and development, with emphasis shifting toward long-term R&D and reducing financial support for near-term technologies. In addition, there has been a reduction in direct Federal involvement in commercialization efforts, while retaining incentives such as tax credits for renewable energy resource development.

The following points summarize the key findings of our recent analysis of OTEC: First, despite Federal expenditures of over $200 million in the past 10 years, the high first cost and the uncertainty of economic viability for a large—that is, over 100,000 kilowatts—OTEC plant continue to deter major commercial investments in this technology. Second, there are more near-term possibilities for developing a power-producing OTEC system, and these appear to be in the smaller sizes, from 1,000 to 10,000 kilowatts, and also appear to be for shore-based locations on tropical islands where comparative energy costs are very high. There are also opportunities for combining power production with other end uses, such as aquaculture and fresh water production. In addition, only very small—that is, 100 kilowatts or below—OTEC test plants have been operated to date, and these for only very short periods of time, sometimes several days up to a few months. Much more test data are probably needed even before a small-scale commercial plant is built. However, we have also noted that a few commercial firms have stated that they are ready to build an island-based system under the right economic conditions. Other than the United States, only Japan apparently has invested substantially in OTEC development and also has funded some of these very small, pilot test plants. Several other countries have also done studies, tests, and made proposals for small, island-based OTEC plants. Under most circumstances, looking at the economics, with prevailing fossil fuel costs, both oil and coal, the cost of OTEC-produced electricity appears to be considerably higher than more conventional and lower risk fossil fuel alternatives. The present DOE program supports almost all of the U.S. OTEC research now underway, and the budget for the program has been substantially reduced in recent years. Our analysis indicates that the present program lacks long-range goals and that the variety of research projects now underway do not constitute a very coherent plan. If the program is to make effective use of Federal funds, it appears that realistic and achievable goals should be incorporated and the limited funds should be directed at the most important problems. Past legislation has provided financial incentives for private OTEC investment in the form of loan guarantees and tax credits. Many of the OTEC proponents believe that these incentives will be essential for the development of any initial commercial applications and should not be allowed to expire.

This OTA study of OTEC and the findings above were used to structure an OTEC workshop cosponsored by OTA and your committee on February 9 and 10 of this year. The workshop focused on future directions for the Federal OTEC program. The workshop agenda and list of participants are attached to the testimony. We organized the workshop so that the experts in OTEC technology and those involved in current R&D could present their views of a proper direction for the program. We also asked another group, experts in broader energy policy and technology topics, to review the OTEC presentations and discussions and to summarize what appeared to be the most feasible options.

The following points summarize the conclusions from that workshop. The written presentations by individual participants at the workshop have been submitted to your committee. First, there was general agreement that there is justification for Federal involvement in OTEC research, mainly to preserve the option of developing this renewable energy resource if it is needed in the next century. Thus, some modest level of OTEC research for this purpose should be directed at long-term needs and generic, high-risk problems. Second, the present DOE program is not coherent because it contains both the residuals of previous false starts and areas of new and more basic research. The workshop group felt that if long-range goals are to be the focus, the program plan should emphasize generic and fundamental research and eliminate some site-specific and system-specific efforts. There may also be some near-term markets for special, small-scale OTEC systems under certain conditions such as tropical islands, where the alternative energy sources are unusually costly. The workshop group felt that these applications would develop on a case-specific basis and would be useful to monitor. If localized Federal energy development programs in such areas are, in part, justified such as for foreign aid reasons and also OTEC is a technically feasible option, then Federal support for an OTEC pilot operation may be justified. The economic projections for OTEC systems and comparisons with other energy alternatives seem to have provided the Federal Government with about as much information as is possible with the present status of the technology. The workshop group did not feel that further economic analyses would shed light on OTEC economic feasibility until we have some substantial operating experience with real commercial systems. In addition, cost estimates of new concepts are also not very useful in determining economic feasibility, but are useful in identifying fruitful paths for future research efforts. Finally, the workshop group felt that it would be important to maintain at least a modest-sized test facility with a cold water pipe capable of pumping deep water to some shore laboratory. Such a facility would enable researchers to investigate the important generic problems related to developing OTEC technology.

Mr. Chairman, it appears that the Federal OTEC program would be enhanced by a firmer and clearer set of long-range goals for the research, recognizing the limitation of funding and the uncertainties associated with the present state of technology development. Our analysis indicates that the Department of Energy could readily establish such goals using the results of their work to date.

[The prepared statement of Peter Johnson follows:]

## TESTIMONY OF PETER A. JOHNSON

## OFFICE OF TECHNOLOGY ASSESSMENT

Mr. Chairman:

My name is Peter Johnson, and I am the director of the Office of Technology Assessment's study of Ocean Thermal Energy Conversion (OTEC) systems. Thank you for the opportunity to appear before this Subcommittee today on behalf of OTA to discuss our recent staff paper reviewing the status of OTEC development and the results of the OTEC workshop co-sponsored by OTA and your committee.

The OTA staff paper titled, "Review of Ocean Thermal Energy Systems," was published in January 1984 and was prepared at the request of your committee. We were able to prepare this review with a rather modest level of staff effort because we had conducted two previous studies of OTEC, in 1978 and in 1980. The 1984 work was undertaken with particular attention to alternative technical paths for the OTEC concept, to current evaluation of OTEC economic feasibility, and to the future markets for OTEC products. We also evaluated the present DOE OTEC program to determine whether clear goals have been set and whether a rational approach to meet those goals is in place.

As you know, OTEC is a solar thermal energy converter, tapping the energy resource created by the temperature difference between solar heated surface and polar cooled subsurface oceanic waters. Numerous OTEC concepts have been proposed ranging from shore mounted plants to moored or drifting offshore plants. Sizes could vary from plants producing a few hundred kilowatts to those generating hundreds of megawatts.

Two basic OTEC techniques have received the most investigation: the so-called closed and open cycles. Also, while electricity generally has been considered the primary OTEC product, secondary products such as ammonia or methanol also have received considerable attention, especially for moored or drifting OTEC plants located in remote areas. In the latter case, the electricity produced by the plant is used to produce hydrogen by electrolysis of water. The hydrogen, in turn is used to synthetically produce methanol or ammonia. To produce methanol, a source of carbon is also needed and coal is the primary candidate.

The U.S. Department of Energy (DOE) (and its predecessor, the U.S. Energy Research and Development Administration, ERDA) has funded an OTEC program since FY 1975, expanding the research effort initiated by the National Science Foundation in 1972. By September 1983, over $200 million had been spent on federally funded OTEC development. OTEC expenditures and activity peaked in 1980 and have decreased since then. Considerable study of concepts and testing of components have been accomplished. The early design phases of a 40,000 kWe shore-based pilot plant have been completed.

Since 1980, Federal policy towards OTEC has concentrated on research and development with funding emphasis shifting toward long term R&D, while reducing R&D financial support for near term technologies. In addition, there has been a reduction in direct Federal involvement in commercialization efforts, while retaining incentives such as tax credits for renewable energy resource development.

The following points summarize the key findings of our recent OTEC study:

1. Despite Federal expenditures of over $200 million in the past ten years, the high first cost and uncertainty of economic viability for a large (100,000 kWe +) OTEC plant continue to deter major commercial investments in this technology.

2. More near-term possibilities for developing a power-producing OTEC system appear to be in the smaller sizes (1,000-10,000 kWe) for shore-based locations on tropical islands where comparative energy costs are very high. There are also opportunities for combining power-production with other end uses such as aquaculture and fresh water production.

3. Only very small (100 kW) OTEC test plants have been operated to date and only for short periods of time (several months). Much more test data are probably needed even before a small-scale commercial plant is built; however, a few commercial firms have stated they are ready to build an island-based system under the right conditions.

4. Other than the United States, only Japan has invested substantially in OTEC development, although several other countries have done studies, tests and made proposals for small, island-based OTEC plants.

5. Under most circumstances, with prevailing fossil fuel costs (both oil and coal), the cost of OTEC-produced electricity appears to be considerably higher than more conventional and lower risk fossil fuel alternatives.

6. The present DOE program supports almost all of the U.S. OTEC research now underway, and the budget for the program has been substantially reduced in recent years. OTA's analysis indicates that the present program lacks any long-range goals and that the variety of research projects now underway do not constitute a coherent plan. If the program is to make effective use of Federal funds, realistic, achievable goals should be incorporated and the limited funds should be directed at the most important problems.

7. Past legislation has provided financial incentives for private OTEC investment in the form of loan guarantees and tax credits. Many OTEC

proponents believe that these incentives will be essential for the development of any initial commercial applications and should not be allowed to expire.

The OTA study of OTEC and these findings were used to structure an OTEC workshop which was co-sponsored by OTA and your Committee on February 9 and 10, 1984. The workshop focused on future directions for the Federal OTEC program. The workshop agenda and list of participants are attached to my testimony. We organized the workshop so that the experts in OTEC technology and those involved in current OTEC R&D could present their views of a proper direction for the program. We also asked another group, experts in broader energy policy and technology topics, to review the OTEC presentations and discussion and to summarize the most feasible options.

The following points summarize the conclusions from that workshop. The written presentations of individual participants at the workshop have already been submitted to your committee.

1. There was general agreement that there is justification for Federal involvement in OTEC research to preserve the option of developing this renewable energy resource if it is needed in the next century. Thus, some modest level of OTEC research should be directed at long-term needs and generic, high-risk problems.

2. The present DOE program is not coherent because it contains both the residuals of previous false starts and areas of new and more basic research. The workshop group felt that, if long range goals are to be the focus, the program plan should emphasize generic and fundamental research and eliminate site specific and system specific efforts.

3. There may to be some near term markets for special small scale OTEC systems under certain conditions such as tropical islands, where alternative energy sources are unusually costly. The workshop group felt that these applications would develop on a case specific basis and would be useful to monitor. If localized Federal energy development programs in such areas are, in part, justified for foreign aid reasons and OTEC is a technically feasible option, then Federal support for an OTEC pilot plant may be justified.

4. Economic projections for OTEC systems and comparisons with other energy alternatives have provided the Federal government with about as much information as is possible with the present status of the technology. The workshop group did not feel that further economic analyses would shed light on OTEC economic feasibility until we have some substantial operating experience with commercial systems. Cost estimates of new concepts are also not very useful in determining economic feasibility but are useful in identifying fruitful paths for future research efforts.

5. Finally, the workshop group felt that it would be important to maintain at least a modest sized test facility with a cold water pipe capable of pumping deep ocean water to a shore laboratory. Such a facility would enable researchers to investigate the important generic problems related to developing OTEC technology.

Mr. Chairman, it appears that the Federal OTEC program would be enhanced by a firmer and clearer set of long range goals for the research, recognizing the limitation of funding and the uncertainties associated with the present state of technology development. Our analysis indicates that the Department of Energy could readily establish such goals using the results of their work to date.

Attachment 1

House Committee on Science and Technology
and
The Office of Technology Assessment

## Workshop on Ocean Thermal Energy Systems
February 9-10, 1984

## PARTICIPANTS

### Energy Panel

John Andelin, Office of Technology Assessment
Daniel Dreyfus, Gas Research Institute
Lloyd R. Lawrence, Mechanical Technology, Inc.
Gene Mannella, Panel Chairman, Electric Power Research Institute
Richard Pei, Rand Corporation
Joel Weiss, Accurex Solar

### OTEC Technical Participants

Robert Cohen, Giannotti & Associates, Inc.
John Craven, Department of Ocean Engineering, University of Hawaii
Thomas H. Daniel, The Natural Energy Laboratory of Hawaii
Bud Francis, The Johns Hopkins Applied Physics Laboratory
Modesto Iriarte, Center for Energy and Environment Research,
  University of Puerto Rico
Richard Norling, MicroPower, Ltd.
William Richards, Ocean Energy Technology Division,
  Department of Energy
Louis Rotundo, Florida Solar Energy Center
Norman F. Sather, Argonne National Laboratory
Ben Shelpuk, Solar Energy Research Institute
Joe Vadus, Office of Oceanography & Marine Services,
  National Oceanic and Atmospheric Administration
Jay Yaffo, Ocean Thermal Corporation

### House Science and Technology Committee Staff

Gene Frankel
Bob Kripowicz
Daniel Steinway

### Office of Technology Assessment Staff

Dale Brown
Peter Johnson
Dick Rowberg

Attachment 2

House Committee on Science and Technology
and
The Office of Technology Assessment

## Workshop on Ocean Thermal Energy Systems

Agenda

February 9, 1984

9:00 - 9:15 Introduction (by Gene Manella, Energy Panel Chairman)
  Purpose of Workshop (by House Science and Technology Committee Staff)
  Introduction of Participants

9:15 - 10:00 History and status of Department of Energy OTEC program
  Bill Richards, DOE
  Discussion

10:00 - 10:15 Coffee Break

10:15 - 12:30 5-10 minute presentations by technical participants

12:30 - 1:30 Lunch

1:30 - 5:00 Discussion topics
Led by Gene Manella

1. Status of OTEC technology
    - What are the current technological problems regarding commercial OTEC development?
    - What are the R&D needs? Priorities?
    - What is the status of OTEC development relative to other renewable energy systems?

2. Markets and competition
    - What is the potential contribution of OTEC to U.S. energy needs, in the near- and long-term?
    - Are there viable markets for OTEC power or products in U.S. territories or other island nations?
    - How do the economics of OTEC systems compare to those for other energy technologies?
    - What is the significance of alternative OTEC products, such as fuels, fresh water, or mariculture products, to the competitiveness of OTEC systems?

3. Appropriate Federal program goals
    - What is the national interest in funding an OTEC program? For example:
        Reducing uncertainty for private industry
        Maintaining U.S. pre-eminence in OTEC technology
        Energy independence
    - What is achievable?

Attachment 3

## Workshop on Ocean Thermal Energy Systems

Energy Panel Session

Agenda

February 10, 1984

9:00 - 10:30 Overall program strategies

1. Technological goals
    - Given limited resources, should the Federal effort be focused on one or a few objectives?
    - What is the value of a demonstration project compared to diverse R&D projects?
2. Market considerations
    - How would termination of the current program affect market development or entry by U.S. industry?
    - Should financial incentives be given greater importance relative to R&D efforts?
    - International competition - is it a concern?

10:30 - 10:50 Coffee Break

10:50 - 12:00 Funding levels - general considerations

- Is it worth maintaining a Federal OTEC program at the current funding level?
- If funding is not increased, should it be targeted to a different array of programs and activities?
- Is current or additional funding justified for this technology, in the context of competing energy development programs?

12:00 - 1:00 Lunch

12:00 - 2:00 Summaries of choices

Conclusions by Energy Panel members concerning options available to the Science and Technology Committee in setting goals for the Federal OTEC program and in developing strategies to achieve those goals.

Mr. FUQUA. Thank you very much, Mr. Johnson. Dr. Firstman?

## STATEMENT OF DR. SIDNEY I. FIRSTMAN, PRESIDENT, BIOMASS ENERGY RESEARCH ASSOCIATION, WASHINGTON, DC, ACCOMPANIED BY WILLIAM S. BULPITT, CHIEF, MECHANICAL SYSTEMS DIVISION, ENGINEERING EXPERIMENT STATION, GEORGIA INSTITUTE OF TECHNOLOGY, ATLANTA, GA, AND MARILYN J. RIPIN, DIRECTOR, ADVANCED TECHNOLOGY, JAYCOR, ALEXANDRIA, VA

Dr. FIRSTMAN. Good morning, Mr. Chairman, members of the staff. I am pleased to have this opportunity to address the committee. My name is Dr. Sidney I. Firstman of the Georgia Institute of Technology, and I am here today as the president of the Biomass Energy Research Association. My testimony has been submitted in complete form, so I will just summarize a few comments at this time. I'd like to start by highlighting a few notions of the role of biomass within the overall national energy picture. And I would like to point out that, unlike the other renewable energy technologies, biomass is able to produce liquid and gaseous fuels directly, to offset imported oils and minimize depletion of our own oil reserves. I would also point out that, according to an OTA study, biomass is believed to be able to contribute between 10 to 15 percent of our Nation's energy supply by the year 2000, provided that the right kinds of investments are made in this technology. The ability to produce liquid or gaseous fuels suitable for substitution in current supply systems makes biomass an ideal backup for energy disruptions and other shortages potentiall threatening to our national security. And, finally, as an additional benefit which our association pointed out last year in testimony before this committee, we believe biomass has the potential to create jobs, particularly in rural areas where job creation has traditionally been a very difficult problem. Before turning to our recommendations for this year, I'd like to highlight a couple of success stories, programs that have reached the stage of things we like to talk about to show you where your past investments are currently bearing real fruits. First, an 8-year research program at the University of Washington designed to develop black cottonwood for short rotation cultivation for fuel or chemical uses we would like to point out as a model of public-private sector cooperation and DOE-sponsored biomass energy research. Working closely with several forest products companies in the Pacific Northwest, the University of Washington researchers have developed some highly productive black cottonwood varieties and hybrids suitable for fuel and other chemical uses. Cooperative plantings have been established with Crown Zellerbach Corp., Lamb-Weston, Inc., and Simplot Corp., for which these companies are providing all land, labor, and materials for planting, maintaining, and monitoring the black cottonwood cuttings provided by the university. The largest of these plantings involves several hundred acres under intensive cultivation, and we anticipate that full commercial short-rotation cultivation of these black cottonwood varieties is going to be with us in 2 or 3 years. Another success story, a wood-burning gas turbine system developed by Aerospace Research Corp. of Roanoke, VA., with some DOE support, shows promise for efficient and inexpensive generation of electricity at facilities located in the midst of its feedstock supply—the forest. A 3-megawatt system is currently being built for installation at Red Boiling Springs, TN, where it is expected to be producing power for the Tennessee Valley Authority grid by the summer of this year, using locally available sawdust and wood residues. This is a truly unique adaptation of a technology normally used for aircraft and marine applications. Finally, before posing our budget recommendations, I'd like to note four features of the recommendations we'll make to you.

For one, this year for the first time we surveyed the members of BERA to determine their R&D suggestions, and because our membership is composed of both public, institutional, as well as private sector interests involved in biomass research and development, we believe our membership's views and inputs, which I'll present to you, will be of interest and use to your committee as you make your difficult decisions on money allocations.

Second, in my testimony that follows—well, in fact, right now—I want to pose a new category of energy investment, at least a new category for biomass, that of cost share in large-scale implementation.

Talking at this point aside from the mainstream of biomass research and development and conversion technologies, we want to point out that the production of medium Btu gas by both steam and steam/oxygen gasification, the direct result of the Federal research program, have advanced to the point where major private investment is being attracted.

Two examples: The Battelle-Columbus medium Btu gasification process is now ready for scale up and negotiations are in progress for a jointly funded industry/Government pilot project.

Further west, the SERI/International Harvester methanol project has developed a fixed-bed downdraft steam/oxygen gasification system for use in small-scale methanol plants. Finally, let me not forget the IGT Renugas Process Research Unit, specifically designed to obtain accurate scale-up date on the thermal conversion of biomass to medium Btu fuel gas or synthesis gas, is also ready for such commercial investment. Against this background of technology ready and almost ready for commercial investment, BERA believes that medium Btu gasification, as it shows real near-term potential, we urge support for this technology. We urge continued support for this technology. We are particularly supportive of joint DOE/industry efforts like these I discussed, and believe that a separate, appropriately large budget, perhaps on the order of $5 million, should be established to support the Government share of these Government/industry programs. Moreover, we believe that this investment in cost-sharing the full-scale development of market-ready technology should be made over and above the continuing R&D program. The continuing R&D program would be seriously handicapped were these major cost-share investments made from normal program funds. The third point I want to make is that the R&D budget that we will propose does not include moneys for alcohol fuels or municipal solid wastes. We recognize that these are important elements in the overall research program for bioenergy resources, but we want to yield to the statements of the groups most involved in their development as to the amounts necessary for viable activities in these areas. We are pleased to share a good working relationship with groups such as the National Wood Energy Association and the Renewable Fuels Association and trust that their views will be considered in the final consideration of budget levels. I want to turn briefly now to our budget suggestions, which are contained in the submittal to you. And as I go through this, I want to make a couple of points—in advance, rather. One is that we are looking toward, as we have before, a balanced program between the development of biomass feedstocks and their conversion into useful fuels. Moreover, we are posing three new categories of programs for your consideration. We are posing a category of harvesting research, which I'll say more about in a minute; a category of supporting research; and a category of integrated system planning. A few highlights of our budget submittal to you: In the area of biomass feedstock production research, we look first to short rotation woody crops; suggest a budget level of $4,200,000, and observe that there is an important need for scale-up experiments for promising short rotation woody crops species, including expanding the range and sites in which the species are grown and studying the resistance to disease and pests of these new species. Funding is also needed to conduct research in genetic selection and tissue culture, where we believe there is potential high payoff.

In the category of aquatic species, we suggest a funding level of $3,700,000, and we note here that aquatic species research should focus on screening studies of microalgae in laboratory and small-scale field experiments to provide high sustained yields of high-value oils which can directly replace diesel fuels. In the category of herbaceous species, we recommend funding of $3 million, and we note here that for species selected for further research—several of these we suggest in more detail in written testimony—we look to small-scale experiments to provide data on the effects of spacing, fertilizer, irrigation, nutrients, and other methods for improving overall productivity.

Our fourth category of funding here is harvesting research, which I noted a few minutes ago was a new category, we suggest funding this year of $1,200,000, and we note that harvesting represents the single largest cost in growing crops for energy. The program needs to sponsor more equipment research in conjunction with scaling-up, such as the short rotation woody crop experiments as well as in harvesting of herbaceous and aquatic crops. Improvements in cutting, collecting, and transport efficiency are needed for a broad range of crops in order for the growth-to-energy cycle to prove economical.

Turning to the biomass conversion to fuels, our first category is biochemical conversion, wherein we suggest a budget on the order of $3 million, and I note quickly that this does not include investment in the alcohol fuels program, which we mentioned earlier was a separate category. We note here that the fundamental objective of bioconversion research is the development of viable technologies for the conversion of lignocellulosic materials to liquid fuels, and we point out in our testimony several areas for continuing research and development.

In the category of thermochemical conversion, we look for a budget of $7 million. The thermochemical conversion research program has recently concentrated upon the development of medium Btu gas or synthesis gas and liquid fuel technologies. Production of medium Btu gas by both steam and steam/oxygen gasification has been, as I pointed out earlier, a major achievement of the Federal program. Here, in addition to the technologies which we believe are ready for industry investment, research has been initiated on promising innovations that can further improve the economics of medium Btu gasification as well as methanol production, and we seek funding of these areas of research.

Finally, in this category, BERA notes that recent efforts to commercialize low-Btu gasifiers have disclosed several technological limitations. BERA recommends funding be directed now to intensive and immediate research and development focused to overcoming these technological deficiencies, so as to maintain the potential for early widespread commercialization of low Btu gasification. We pose a new category called "supporting research." We note, as a biomass energy research association, that a balanced program cannot be maintained without basic or supporting research. This is research such as genetic engineering in the production program and understanding the mechanism of catalytic action in the thermochemical conversion area. These are essential understandings to provide new concepts and improvements. The results of this basic research cannot be measured in quads, but it's nonetheless invaluable in advancing the technological readiness of biomass technologies.

BERA believes a balanced research program would not be complete without supporting research and, as you will see on our budget, we are proposing that that be given a separate category. And there are many detailed suggestions of menu of research, in fact. I want to point out that we are also proposing that the supporting research funds be managed by the several DOE field units that manage the ongoing programs of applied research. This will help insure both relevance of research and the potential use of the research findings.

Environmental studies and analyses, we propose for $1 million of funding, and we note here that the proper development of biomass energy requires a continuing level of attention to environmental issues. Of particular interest to us are studies of wood gasification emissions and harvesting strategies, and the use of woody crops to neutralize or convert toxic waste. Another new category in our submittal is that of integrated systems planning, and we suggest a small budget of $300,000 be directed here, small but necessary. This is a new concept, integrated systems planning, based on the idea of building complete biofuels systems composed of both production and conversion components. The first step in this process will be a planning activity to select the most technically and economically feasible systems. First year activity would be devoted to DOE thinking hard and developing a plan in this integrated systems area.

Finally, we pose a $4,500,000 budget for the regional biomass energy activities program that we were happy to first propose to this committee 2 years ago for funding. Since then, we have observed the birth and early growth of successful, regional biomass energy programs in the Midwest, the Northeast, the Southeast, to build upon the program in the Northwest. This year we have proposed a program be initiated in the Southwest and they be provided funds for initial planning activities.

As I said, these programs are finding support in the regions. They are doing what we believe to be meaningful regionally-focused work, and BERA recommends a regional program should continue to conduct activities in the areas of technology transfer, industry support, and should continue to match local needs to region-specific biomass resources. Our total operating budget, therefore, is $31,900,000 recommended to your committee. Before we turn to questions, let me introduce my colleagues who are here with me to help more fully answer questions: Dr. Marily Ripin, on my right, of Jaycor, and Mr. William Bulpitt, also, of Georgia Tech, who will help me address questions of the committee. I thank you.

[The prepared statement of Dr. Sidney I. Firstman follows:]

# TESTIMONY

BY

DR. SIDNEY I. FIRSTMAN

PRESIDENT, BIOMASS ENERGY RESEARCH ASSOCIATION

Good morning. I am pleased to have the opportunity to address the Energy Development and Applications Subcommittee of the House Science and Technology Committee. My name is Dr. Sidney I. Firstman of the Georgia Institute of Technology, and I am the President of the Biomass Energy Research Association (BERA).

Established in 1982, BERA is a non-profit organization dedicated to furthering basic and applied research, technology transfer, and information and education related to biomass technologies. BERA is comprised of scientists, researchers, private industry, organizations, and universities who firmly believe that biomass technologies can significantly contribute to our nation's energy base. We greatly appreciate the opportunity to once again present our views for the Committee's consideration.

Last year, BERA opposed a seriously deficient Administration request for biomass energy R&D. As you know, the Administration's policy for supporting federally funded R&D has been based on several general criteria.

The Administration asserts that federal funding may be justified when:

- the private sector is unlikely to invest because the benefits do not accrue directly enough to a given company; or, there are so many small companies or the technical risk is too great for any given company to financially justify making an investment in R&D.

- there is significant public benefit to the successful completion of RD&D

BERA supports the rationale these criteria introduce to R&D decision-making. However, we continue to believe these criteria are being inappropriately applied to R&D decisions for conservation and renewable resources. In fact, conservation and renewable resources match the very conditions defined above for the following reasons:

- R&D investments , in fact, will not be made by the private sector alone, which in the case of biomass energy is composed of many small companies or companies whose principal business is non-energy related.

- there are still technical risks too large to be taken on by even the largest of these companies.

- there is ample evidence in the large body of policy studies on the issue that point to the very real potential that these technologies have for contributing significantly to the nation's energy resources. Furthermore, this potential can be realized by making relatively modest R&D investments in some advance technical areas.

While these same arguments could be applied to nearly all of the conservation and renewable energy technologies, we believe biomass represents a particularly compelling case for federal funding. First of all, the ultimate strength of biomass energy comes from two attributes. The first, and most important is the unique ability to use biomass to produce fuels which can directly replace liquid and gaseous fuels. Second is the close proximity between resource and user. However, this means that biomass companies are smaller and more dispersed. Clearly in this regard, the criteria for sponsorship fit the situation well.

Perhaps even more crucial is the fact that biomass energy, according to studies such as OTA's, could contribute as much as 10% or 15% of the Nation's energy supply by the year 2000, provided the right kinds of investments are made.

Another consideration is that biomass, more so than any other renewable resource, is inherently small-scale, based on regional and local resources.

The ability to produce liquid or gaseous fuels suitable for substitution in current supply systems makes biomass an ideal backup for energy disruptions and other shortages potentially threatening to national security.

An additional benefit, which as we stated last year has not been adequately studied, is the potential for biomass energy to create jobs - particularly in rural areas where job creation traditionally has been a real problem.

In summarizing,these were the justifications we presented to encourage the reconstruction of the federal biomass effort in FY 1984. Fortunately, many of you on this Committee agreed that biomass technology was indeed a worthy federal investment - one that was likely to accrue excellent benefits for the relatively small amounts invested.Already the investment made in biomass technologies, an investment I must add has been considerably smaller in comparison to other renewable technologies has produced some interesting success stories.

For example, an eight year research program at the University of Washington (UW) designed to develop black cottonwood for short-rotation cultivation for fuel or chemical uses is a model of private-public sector cooperation in DOE-sponsored biomass energy research. Working closely with several forest products companies in the Pacific northwest, UW researchers have developed some highly productive black cottonwood varieties and hybrids suitable for fuel and/or chemical uses. Cooperative plantings have been established with Crown Zellerbach

Corporation, Lamb-Weston, Inc., and Simplot Corporation, for which the companies are providing all land, labor and materials for planting, maintaining and monitoring the black cottonwood cuttings provided by UW. The largest of these plantings involves several hundred acres under intensive cultivation. Fully commercial short-rotation cultivation of these black cottonwood varieties is expected within two to three years.

In another instance, a wood burning gas turbine system developed by Aerospace Research Corporation of Roanoke with some DOE support, shows promise for efficient and inexpensive generation of electricity at facilities located in the midst of its feedstock supply -- the forest. A 3MW system is currently being built for installation at Red Boiling Springs, Tennessee, where it is expected to be producing power for the Tennessee Valley Authority electric grid by the summer of 1984, using locally available sawdust and wood residue. This is a truly unique adaptation of a technology normally used for aircraft and marine applications.

Therefore, thanks to the interest of you and your colleagues, a core biomass program was established which we believe can provide the foundation for achieving the potential of this resource.

The fiscal 1985 program that the Biomass Energy Research Association is proposing is based on our consideration of two factors. First, it takes the 1984 core program and proposes changes, which we believe will substantively strengthen the R&D output. Secondly, this year for the first time, BERA undertook a methodical survey of its diverse membership to glean the best ideas for needed areas of technical research and have included these in our budget proposal. Because our membership is composed of both public, institutional and private sector interests involved in biomass R&D, we believe our membership's views and input will be of interest and use to the Committee as it makes its difficult decisions on money allocations.

Before I discuss the specifics of the program we are proposing I would like to take a moment to focus on a very important point. Whatever the final decisions on funding allocations for this program, we believe it is important that there be a balanced approach to research and development activities in the biomass area.

It is BERA's view that a successful program includes three basic elements First, the bulk of the R&D effort should be devoted to funding the most promising technologies - those that are most likely to be "winners". This area can be termed applied research. In feedstock production activities this applied research, as you will see, should include scale-up experiments to better determine the real production potential of promising species on plots of such a size that the effects of monoculture can be assessed. In the conversion area there are promising technologies such as medium Btu gasification that are potential winners but need additional research to become commercially ready. We believe that it is essential to continue work in this area. Related to this are efforts such as the one I described earlier involving Aerospace Corporation and TVA. These joint industry/government partnerships are producing exciting results and while not reflected in the BERA proposed research budget that will follow, we believe the committee should seriously consider providing funding for these efforts over and above the core program levels.

Also, a balanced program can not be maintained without basic or supporting research. This is research such as genetic engineering in the production program and understanding the mechanism of catalytic action in the thermochemical conversion area, which is essential for providing new concepts and improvements. The results of this research cannot be measured in quads but is nonetheless invaluable in advancing the technological readiness of biomass technologies. BERA believes a balanced biomass program would not be complete without supporting research, and as you will see on the attached budget, we are proposing that it be given a separate category. However, we also propose that the supporting research funds be managed by the several DOE field units that manage the ongoing programs of applied research. This will help ensure both relevance of research and the potential use of research findings.

Finally, our balanced program also includes activities that take the best of the technologies and provide the means to get them into the real world. Because biomass is such a regionally based set of technologies and resources, we believe the Regional Biomass Energy Activity funded in last year's budget is a very useful means of accomplishing this type of regional focus to technology needs, opportunities and ultimately technology transfer. For the four regions that are already underway with their programs we would like to point out some of their successful activities to date.

In the Northeast, the program is taking the first comprehensive, region-wide look at the problem of air emissions from wood combustion and is providing assistance to industries in the planning and use of wood for industrial purposes. Another key element of this program is the exchange of information on the available biomass technologies. For example, research indicates that there are approximately 7,000 firms in the 11 northeastern states that could profit from the use of wood. The Northeast Regional Biomass Program is designed to help these firms make the right decisions about their energy needs, thereby saving energy and jobs.

In the Southeast,the program is split between feedstock assesments, technology improvement and technology transfer. The major thrust will be in technology improvement where opportunities are being sought to advance the technologies of all sorts of regional feestocks and convert them to useful forms. One significant goal is to key on one or two of the best technologies for the region and with industry co-funding, demonstrate the chosen technology in such a way that it is adopted by the non-wood industry.

In the Pacific Northwest, demonstrating woody biomass recovery and conversion technology is the primary focus of the program. In the area of conversion, the emphasis will be on the development and proof-of-concept activities for direct combustion and gasification systems including data collection on systems operation, economics and performance. In particular, the focus will be on small fluidized-bed combustion, down draft gasification and producer gas and transport. Innovative harvesting and collection systems will also be developed and supplemented with in-field activities. Complementing these activities will be environmental impact identification and mitigation studies.

The Great Lakes Region will continue to conduct biomass assesment activity using Landsat remote sensing imagery for the whole region and refining this assessment to a level where production and transportation pathways to the resource are known. In addition, they intend to investigate the extent to which biomass and coal can be used in combination to mitigate acid rain and emissions, and will continue to investigate the potential for gasification technology in the region.

BERA is pleased to have had the opportunity to work with several other groups and associations and members of Congress on developing this Regional Biomass Energy Program and continue to firmly support its funding.

In summary, our view is that a well-directed biomass energy technology program should have three basic elements: supporting research; a substantive body of applied research in two major areas:production and conversion; and activities which encourage the regional focus and transfer of these technologies into the Nation's energy system.

Now I will briefly summarize the balanced biomass technology program that BERA supports for 1985 federal funding. First, we are proposing that monies continue to be spent in the core program areas of both production and conversion technologies, including short rotation woody crops, aquatic and herbaceous species, and biochemical and thermochemical conversion. Also, as just stated we strongly support the continuation of a regional biomass program and endorse the addition of a new region in the Southwest. It is our understanding that there are numerous groups and individuals in that region who would enthusiastically embrace such an effort and who are already beginning to discuss how such a program might operate.

In addition to these existing program elements, BERA proposes a few additions which we believe strengthen the work in these areas and improve the timetable for making biomass a real contributor to the Nation's energy supply.

In the production category, we propose that a new program element, Harvesting Research be added. This program element is important to supporting the scale-up activities proposed in the various species research elements. Furthermore, harvesting represents the single largest cost in growing short rotation crops - understanding the methods and tools for making this part of the process more efficient is an important research area.

BERA also proposes the addition of a Supporting Research category for the reasons stated earlier. Basic research is the foundation of a healthy balanced program. Separating basic research in its own category will provide better accountibility for research results and ensure that promising discoveries are quickly infused into the core of the applied research effort. In a similar vein, BERA proposes that an Integrated Systems Planning element be added to the biomass program to begin planning for integrated production/conversion research. Finally, as we suggested last year, we believe DOE should be asked to examine the environmental issues related to biomass development so that no impediments to the ultimate use of the technologies developed will be overlooked.

Aside from the mainstream of biomass for conversion technologies we want to point out that the production of medium Btu gas by both steam and steam/oxygen gasification, the direct result of the Federal research program, have advanced to the point where major private investment is being attracted.

For example, the Battelle-Columbus MBG process is now ready for scale-up and negotiations are in progress for a jointly funded industry/government pilot project. The SERI/International Harvester methanol project has developed a fixed-bed downdraft steam/oxygen gasification system for use in small-scale (120/ton/day) skid-mounted methanol plants designed to keep capital costs low through mass production. Another example, the IGT RENUGAS Process Research Unit, is specifically designed to obtain accurate scale-up data on the thermal conversion of biomass to medium Btu fuel gas or synthesis gas via pressurized fluidized-bed gasification.

BERA believes that medium Btu gasification shows real near term potential and urges that support for this technology be continued. We are particularly supportive of joint DOE/industry efforts like those highlighted above and believe a separate, appropriately large budget, on the order of $5 million, should be established to support the government share of these government/industry programs. This investment in cost-sharing the full-scale development of market ready technology, should, we believe be made over and above the continuing R&D program. The continuing R&D program would be seriously handicapped were these major cost-share investments made from existing program funds.

It should be noted that the budget that BERA proposes does not include monies for alcohol fuels or municipal solid wastes. We recognize that these are important elements in the overall research program for bioenergy resources but must yield to the statements of the groups most involved in their development as to the amounts necessary for viable activities in these areas. We are pleased to share a good working relationship with groups such as the National Wood Energy Association and the Renewable Fuels Association and trust that their views will be considered in the final consideration of budget levels.

With those exceptions, the BERA proposed 1985 Biomass Energy Technology budget totals $31,900,000. As you will see in the attached budget statement, this figure roughly balances work in production and conversion, with smaller increments devoted to the other program elements I just discussed.

We believe this budget and the small increase in funding that it represents, is balanced but lean. We believe it is a rational next step to the program this committee was so instrumental in putting into place last year and we hope it will recieve your full consideration for funding in 1985.

Thank you again for this opportunity to testify, I will be pleased to answer here or in writing, any questions you may have about the ideas we have presented.

# FY 1985 BIOMASS ENERGY TECHNOLOGY PROGRAM

## A. BIOMASS FEEDSTOCK PRODUCTION RESEARCH ($12,100,000)

1. Short Rotation Woody Crops................$4,200,000
There is an important need for scale-up experiments for promising SRWC species including expanding the range and sites in which the species are grown;studying the resistance to disease and pests; and producing other desired energy factors such as improved Btu content. Funding is needed to conduct research in genetic selection and tissue culture where there is potential high payoff. Genetic experiments to identify superior genotypes and research to identify and increase the potential of biologically fixed nitrogen should also be conducted. Research is also needed in the use of Mycorrhiza as a stimulant for plant growth. This can be applied to mine reclamation projects and woody crop production.

2. Aquatic Species.......................$3,700,000
Aquatic species research should focus on screening studies of microalgae in laboratory and small-scale field experiments to provide high sustained yields of high-value oils which can replace diesel fuels. Research is also needed in the area of utilizing dried aquatic weeds as a fuel

source, e.g. as a substitute for peat moss in the production of pellets used in providing heat.

3. Herbaceous Species......................$3,000,000

Monies should be directed towards laboratory and greenhouse research to provide reliable data on candidate species. For species selected for further research, small-scale experiments should provide data on the effects of spacing, fertilizer, irrigation, nutrients and other methods for improving overall productivity.

4. Harvesting Research...................$1,200,000

Harvesting represents the single largest cost in growing crops for energy. The program needs to sponsor more equipment research in conjunction with scaling-up SRWC experiments to the next size (planting 50 to 100 acre plots of selected trees) and in the harvesting of herbaceous and aquatic crops. Improvements in cutting, collecting and transport efficiency are needed for a broad range of crops in order for the growth-to-energy cycle to prove economical.

B. BIOMASS CONVERSION TO FUELS ($10,000,000)

1. Biochemical Conversion..................$3,000,000

The fundamental objective of bioconversion research is the development of viable technologies for the conversion of lignocellulosic materials to ethanol, methanol and other fuels. Basic biochemistry studies have shown photosynthesis coupled with hydrogenase enzymes can produce hydrogen by water- splitting.This work should be extended. In anaerobic digestion, several promising pretreatments have been identified that render resistant lignocellulose more susceptible to digestion organisms;these,too deserve continued investigation. An alternative to pretreatments is to develop a more effective organism (inoculums) to digest untreated lignocellulosic feedstocks. It is recommended that money be allocated to improve the IGT wood digestion inoculum, determine conditions optimum for its growth and metabolism, and develop a process for its use in converting woody biomass to usable fuel gas. Laboratory and bench-scale studies should be conducted to determine the best reactor type and operating conditions for maximum conversion of wood to methane. Laboratory digestion tests should also be performed with microalgae using the digestion techniques developed for marine biomass. It should be noted that BERA's recommendations for the biochemical conversion area do not include alcohol or municipal solid waste R&D although we support their inclusion in a balanced research program for biomass.

2. Thermochemical Conversion....................$7,000,000

The thermochemical conversion research program has recently concentrated upon the development of medium-Btu gas(MBG), or synthesis gas and liquid fuel technologies. Production of MBG by both steam and steam/oxygen gasification has been a major achievement of the federal program.

In addition to the technologies discussed previously, research has been initiated on promising innovations that can further improve the economics of MBG and methanol production. The IGT pressurized steam/oxygen fluidized-bed gasification project and the PNL catalytic steam gasification project both introduce valuable new concepts in biomass gasification and deserve continued support . Recently initiated projects explore advanced concepts in pyrolysis technology for the direct production of biomass oils, distillate fuels and chemical feedstocks that could introduce a broad spectrum of new products attainable through thermochemical conversion. Finally, BERA notes that recent efforts to commercialize low-Btu gasifiers have disclosed several technological limitations. BERA recommends funds be directed to intensive and immediate research and development focused to overcoming these technological deficiencies so as to maintain the potential for early widespread commercialization of low Btu gasification.

3. Supporting Research.......................$4,000,000

These important research areas although they do not, in and of themselves, constitute primary technologies deserve support. Valuable subjects for basic supporting research include photosynthesis, microbial metabolism and genetic engineering. In the production area basic photosynthesis research can realize future benefits in improved plant productivity and in developing new biomimetic photochemical conversions. Important supporting research for conversion technologies include electrochemistry and chemical conversion, solvent and supercritical fluid interactions, engineering modeling and heat transfer technology. Energy-efficient product recovery technology would greatly improve the economics of many bioconversion processes and practical methods for ultra fast heat transfer would enhance the prospects for flash pyrolysis. However, supporting research is necessary. BERA recommends investigation of the effects of digestor operating variables on the coproduction of gas and chemicals which would optimize overall biomass conversion efficiency. BERA also recommends the study of catalytic reforming of liquids produced in thermochemical biomass reactors; catalyst additions to the gasification system can be used to increase gas yields. Finally, investigation is needed the effects of structural components (cellulose, lignin, etc.) of biomass on its gasification behavior. BERA strongly suggests that it is most appropriate to manage supporting research through the corresponding primary technology programs that the supporting research will most affect.

## C.ENVIRONMENTAL STUDIES AND ANALYSES (\$ 1,000,000)

The proper development of biomass energy requires a continuing level of attention to environmental issues. Of particular interest are studies of wood gasification emissions and harvesting strategies, the use of woody crops to neutralize or convert toxic waste;and, reducing agricultural run-off as part of a non-point source water pollution program. In addition, the program must devote increased attention to long-range environmental planning as was pointed out by ERAB.

## D. INTEGRATED SYSTEMS PLANNING (\$ 300,000)

This is a new concept based on the idea of building complete biofuels systems composed of both production and conversion components. The first step in this process will be a planning activity to select the most technically and economically favorable systems. First year activity would be devoted to DOE developing a plan for integrated systems.

E. REGIONAL BIOMASS ENERGY ACTIVITIES (\$4,500,000)

The successful regional biomass energy programs currently underway in the Northwest, Northeast, Midwest and Southeast should continue in 1985. In addition, a new regional program in the Southwest, should be established with appropriate monies for initial planning activities. The regional programs should continue to conduct activities in areas of technology transfer,obtain industry support, and should continue to match local needs to region specific biomass resources.

| | |
|---|---|
| TOTAL OPERATING BUDGET | \$31,900,000 |

Mr. **Fuqua**. Thank you very much. We are very delighted to have you here today.

Dr. Berdahl, why do we need good solar resource data? If we had it, who would be the user of it?

Dr. **Berdahl**. Well, there are quite a variety of uses, but the fundamental use is simply to plan solar systems adequately, then design them, and then operate them.

Now in planning a solar system, you usually have to look a number of years into the future. Whether it's the purchase of a solar system for a home or the design of a powerplant, one wants to know how much energy the powerplant's going to produce.

One of the important technical quantities which you need to know is simply how much solar radiation is available. I think it's unfortunate that we haven't had a more systematic program of measurements, so that that information is available.

I might also say that there are lots of uncertainties when you plan for the future. We don't know, for example, what future oil prices will be. We don't know what future interest rates will be. But we can find out what the future availability of solar radiation will be with a modest investment of funds. I wish I could tell you how to reduce these other major uncertainties, but this one particular uncertainty, I think if we simply have a program where we measure the solar radiation levels and do sufficient analysis with the data to make sure that it's really useful to people who design solar systems and who plan them, then we will have done the job. It just takes time. There's not too much question, I think, as to what really needs to be done. There was a workshop in 1973 by the National Science Foundation which made recommendations. A program was essentially put in place to carry out those recommendations in the seventies. Now the program has been virtually eliminated, and what's necessary is a continuous, steady application of a small amount of funds to the problem in order to provide the information we need.

Mr. **Fuqua**. If they succeed in blocking the Straits of Hormuz, I think we'll find out pretty soon what the price of oil will be, and these technologies will look a lot more attractive.

Dr. **Berdahl**. Yes, it's certainly true that public interest fluctuates in relation to oil prices.

Mr. **Fuqua**. How accurate must this data be? What we currently have is not that accurate?

Dr. **Berdahl**. Well, I can quote or provide information, if you would like, on the side which shows that in many cases the data that one would like to use contains errors as large as 20 percent. There is data available that can be used. Excessive precision certainly isn't necessary. What we've recommended is that measurements be made with 5 percent accuracy in the hope that, based on those measurements, one can provide data for design and for planning with about a 10 percent accuracy. If we can do that, we feel we've done our job.

Mr. **Fuqua**. You discussed this some in your testimony, but could we do this in 2 or 3 years or do we need a much larger base of data?

Dr. **Berdahl**. Having personally analyzed solar radiation data from one location and another, participating in a project some years ago, I can say that when you look at a record of, say, 4 years of solar radiation data, you're not quite sure whether the years involved were normal or not. So one needs a sufficiently long record, a sufficiently consistent record; 10 years is highly desirable; 5 years is a bare minimum to produce usable, reliable data. I think as we monitor many other quantities of our environment, like wind speed and air temperature, we should also monitor the solar radiation levels on a continuous basis, so that when one wants to design, one can use the last 10 years, the most recent 10 years of data, for design or for estimation of the solar flux in the future.

Mr. **Fuqua**. Well, is that data available today? Can we expand on the data base that we currently have?

Dr. **Berdahl**. Yes, and certainly there is a substantial amount of information. Part of the problem is that the longest coherent data sets end about 1970, and one would like to have fairly currently data. But, beyond that, there is a problem of calibration with the old data. The Department of Energy funded work to, what was called "rehabilitate" solar radiation data that was available in the seventies, and an exhaustive process of editing and trying to correct solar radiation data was gone through. And there is evidence that even that process left systematic errors of 10 percent in the data, and we know that there will be other errors in the data that we don't know about. So the historical data is usable, but I think it's not high enough quality; it's not desirable quality; and it's also historical data. We would like to have the last 10 years worth of data, not the data that was taken several decades ago. When the volcano erupted in Mexico recently, El Chichon, it reduced the direct radiation levels—that component of the radiation coming directly from the disk of the sun—by on the order of 20 percent over much of the United States for a period of months. The effect lasted over a year, and we need to have a handle on that sort of thing and we need to take current data so that we're aware of this kind of change in solar radiation levels.

Mr. **Fuqua**. What was the rationale that NOAA used for not requesting any funds for this? And what is your opinion of that rationale?

Dr. **Berdahl**. It's really very difficult for me to draw conclusions as to what's happened in detail. I certainly know that NOAA signed a letter of agreement with the Department of Energy agreeing in principle to operate the network and to request funds from Congress. I can tell you just in terms of the results, what is coming out of the system, and that there isn't good data coming out of the measuring system. Essentially, nothing's being done. I think you could say the same thing for the Department of Energy program, but it seems to me that—maybe I'm naive, but it seems to me that, if funds were earmarked for the budget, specifically for solar resource assessment, a portion in the NOAA budget, a portion in the DOE budget, then the job would simply get done, because the people certainly at the working level in those agencies are very interested and eager to do a good job. They just haven't had the support.

Mr. **Fuqua**. Did NOAA request that and it was eliminated by OMB or they never got out of NOAA?

Dr. **Berdahl**. I'm not certain where the request ended.

Mr. **Fuqua**. Mr. Johnson, according to the workshop, the OTEC workshop, that was conducted, what's the national interest in funding an OTEC R&D program?

Mr. **Johnson**. Well, it appears that the major national interest that the participants in that group perceived was one of a very long term benefit, which would occur after the end of this century, sometime in the 2000–2020-year range, where we are very uncertain about what the alternative energy sources might be. And OTEC has the possibility of becoming an energy resource which has certain advantages. Even though we do not know today what the economics might be, we do know that it could possess certain environmental advantages—very clean kind of energy production. So if we're looking into the long term, into the next century, it appears that it would be prudent to keep the option open for developing such a technology in that long term. In the short term, there appears to be some very specific and unusual applications of OTEC in places around the world. Many of these locations are not very close to the United States, of course, because the resources are mainly in the tropical oceans, but we do have one State, Hawaii, and a territory, Puerto Rico, and also the Virgin Islands, which have OTEC resources near to them. And there is some possibility of developing an OTEC system at those locations as well.

Mr. **Fuqua**. Is it worth keeping the funding level at approximately the fiscal year 1984 level, which is around $5.5 million?

Mr. **Johnson**. It appears that that funding level is adequate for some of the basic R&D that needs to be done. If one were to take the high risk and develop—try to develop an operating system in the near term, then, of course, a lot more funding would be needed, but to keep the option open for the long term and to do some of the basic research, it appears that the present funding level is a good one.

Mr. **Fuqua**. Well, what would be some of the priority items in a modest technology program?

Mr. **Johnson**. Well, some of the major priority items have to do with looking at those areas that affect the design of an OTEC system, such as heat exchanger work, such as biofouling work, such as looking also at some of the alternate concepts of a system. As I said in my testimony, most of the effort has gone into a closed cycle OTEC system, and at present there are proposals to look into some alternate cycles now. What you do when you do that is you trade some of the difficulties of designing and building heat exchangers for different technical problems, such as in an open cycle system you would be flashing seawater into steam and running that to a turbine, and there are certain turbine problems that you might run into when you're doing that sort of thing. There's a lot of work to be done in those areas. So it's sort of a combination of doing some tests on components and some look at the basic problems, technical problems, with the components in the systems, and looking at some new concepts, looking at open cycle concepts.

Mr. **Fuqua**. You mentioned in your testimony that we—I think the way I understood it—that we would not know the economics of this compared to other technologies until we had an operating commercial system. Is there anything that has changed that? I mean, is there anything—we can't get a ball park of economics?

Mr. **Johnson**. Well——

Mr. **Fuqua**. Compared to other technologies?

Mr. **Johnson**. Yes. I think that the ball park economics compared to other technologies at the same stage of development is available today, and we put some of that information in our study. What doesn't appear to be very fruitful is to continue to do a lot more economic analysis, because we have numbers. The numbers are not accurate. They have quite a wide spread to them. And there's no way, really, to make them accurate by doing more economics work. The only way to make them accurate is to have some operating systems on which to base your confidence in those numbers.

Mr. **Fuqua**. Dr. Firstman, you made the recommendation for harvesting research. What activities would be carried out by a program of that type?

Dr. **Firstman**. Mr. Chairman, let me pass the microphone to Mr. Bulpitt, who I think can more adequately respond to your issue.

Mr. **Bulpitt**. Mr. Chairman, there's a number of activities that are going on in the area of tree growth and woody biomass growth that require optimization and further activities in the area of harvesting equipment. Some private corporations such as Georgia Pacific and some other pulp and paper companies have done work in these areas, but they have never quite come to the final conclusions that they need in terms of optimizing systems that will help minimize the cost of harvesting on various types of terrain that are encountered in different areas of this country. And the Department of Energy, to this point, has not participated very widely in this area, and we feel that, judging from the interest that has been generated in the area of biomass and the knowledge of systems that have been installed to use these feedstocks through DOE programs over the past several years, the other component now needs to be improved upon, and this is the supply issue. That's where the harvesting equipment would help improve——

Mr. **FUQUA**. Would it take a different type of equipment than what they're currently using in pulp and paper harvest?

Mr. **BULPITT**. In some instances it would because you don't necessarily need the same characteristics of feedstock that you do for a conventional pulp and paper operation. You can use smaller, less desirable wood species, for example, for fuel wood.

Mr. **FUQUA**. Are any of the activities that you're recommending under supporting research already being carried out in the biomass program, particularly by the Office of Basic Energy Sciences?

Dr. **FIRSTMAN**. Dr. Ripin will speak to that, Mr. Chairman.

Mr. **FUQUA**. I assume it would be combustion and some of those——

Dr. **RIPIN**. Well, the answer is yes and no. In some areas, looking at basic photosynthesis, the Office of Energy Research is interested in that issue, but they have, of course, a much smaller budget than the Biomass Division, so they look at it in a much smaller way. Other areas that we're recommending—for example, the genetic engineering—we would recommend that that be done specifically with energy trees. The Office of Energy Research will often look at the same issue but at a much more academic level. They'll look at it for any species where they feel they can further the base of knowledge. What we're recommending for the Biomass Division is that they stick to species and issues that are related, definitely related to energy and to their programs but are more basic than what they're doing.

Mr. **FUQUA**. None of the forestry schools that we have are—I think just about every land grant college has a forestry school of some fashion—they're not looking at photosynthesis and new types of materials in their work?

Dr. **RIPIN**. Oh, of course. People are looking at photosynthesis for different reasons all over. It's the basic issue of using the Sun and of growing anything. Biomass would, of course, have to be informed to make sure that their research is directly applicable to energy and not duplicative, but there is enough work to be done, and I think that there could be money in the biomass budget to do that, also.

Mr. **FUQUA**. What mechanisms would you recommend to DOE to use to support the Government/industry pilot projects in medium Btu gasification, using some of the DOE-developed technologies?

Dr. **FIRSTMAN**. The mechanisms that come to mind are those that we've seen in other areas, where there is a program which is available under a cost-share opportunity. They have taken various forms. PON, the Program Opportunity Notice, has been a popular one that DOE has used in which there's opportunities for commercial interest to come forward and to pose a cost share proposition to the Government. Cooperative agreements have been put in place and other such activities. So there's a variety of mechanisms, but it all comes up to the Government and industry coming to the table and finding some way to cost share the development, cost share the ultimate risk. Though we know a lot about the technology, we've had it in the laboratory, we've scaled it up on our campuses and in our laboratories, when you still take it that next step to commercial size—as the synfuels program has shown us—there are just many questions that you don't even think about until you begin to scale, and that's where the risk is and that's where the Government role would be, to my mind, in continuing the support for the still relatively high risk but in a partnership with the industry in a variety of cost-share negotiations.

Mr. FUQUA. And particularly in scaleup?

Dr. FIRSTMAN. In scaleup, yes, sir; scaleup to dimensions that we've not dealt with before which make them commercially viable.

Mr. FUQUA. Thank you, gentlemen—Dr. Berdahl, Mr. Johnson, Dr. Firstman. We appreciate your contributions here this morning. It's been very helpful to the committee.

Thank you very much. The committee will stand adjourned.

[Whereupon, at 11:30 a.m., the committee recessed, to reconvene at the call of the Chair.]

[Questions and answers submitted for the record follow:]

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
MARILYN LLOYD, TENN.
DOUG WALGREN, PA.
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TOM LEWIS, FLA.

HAROLD P. HANSON
Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID S. JEFFERY
Minority Staff Director

February 15, 1984

Hon. Pat Collins
Under Secretary
Department of Energy
Washington, D.C. 20585

Dear Mr. Collins:

Attached are a number of questions regarding the Department's FY 1985 budget request for conservation, solar, and geothermal energy research and development. The answers will be most helpful to the Committee as it marks up the FY 1985 DOE Civilian Research and Development Authorization next month.

We appreciate your willingness to testify before the Subcommittee on Energy Development and Applications, and would like to have your written answers to the enclosed questions no later than March 9.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Fcw
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**Department of Energy**
**Washington, D.C. 20585**

March 9, 1984

Honorable Don Fuqua
Chairman, Subcommittee on Energy
  Development and Applications
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

On February 28, 1984, Under Secretary Pat Collins appeared before your Subcommittee regarding the FY 1985 budget request for conservation, solar, and geothermal energy research and development. With your letter dated February 15, 1984, you submitted written questions for our response that would be helpful to the Committee as it marks up the authorization.

Enclosed are the answers to the above-mentioned questions.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

for Thomas H. Pretorius

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

# POST-HEARING QUESTIONS

FOR

SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ON THE

FY 1985 DEPARTMENT OF ENERGY BUDGET

DEPARTMENT OF ENERGY WITNESS
WILLIAM PATRICK COLLINS, UNDER SECRETARY
U.S. DEPARTMENT OF ENERGY

FEBRUARY 28, 1984

QUESTIONS FROM THE MAJORITY

Question 1: The Administration has requested capital equipment funds of $2.5 million for buildings and community systems, $4.4 million for industrial energy conservation, and $3.4 million for energy conversion and utilization technologies. For each request, please specify how the funds will be allocated by sub-program and by national laboratory, and provide a list of specific items to be procured.

Answer: A listing by subprogram of capital equipment to be purchased is attached.

## BUILDING ENERGY RESEARCH AND DEVELOPMENT

## FY 1985 CAPITAL EQUIPMENT

| BUILDING SYSTEMS SUBPROGRAM | (Dollars in thousands) |
|---|---|
| Lawrence Berkeley Laboratory | |
| Windows and Daylighting | |
| Expand capability of MoWiTT module to permit simultaneous dual-orientation testing | 200 |
| Building Energy Use Simulation | |
| Two 176 megabyte disk drives @$18K | 36 |
| Two tape drives @$22K | 44 |
| Energy Performance of Buildings | |
| Mobile infiltration and ventilation efficiency measurement system (MIVE) | 150 |
| Multi-chamber AC pressurization apparatus | 50 |
| Passive wall thermal performance measurement system | 75 |
| Building Energy Data Acquisition | |
| Field monitor data acquisition system for BECA | 50 |
| Two Microprocessor data acquisition systems @$5K | 10 |
| Ventilation and Indoor Air Quality | |
| Gamma spectrographic source monitor | 10 |
| Two continuous radon monitors @$5K | 10 |
| Field computer system | 10 |

BUILDING SYSTEMS SUBPROGRAM (cont'd)

Lawrence Berkeley Laboratory (cont'd)

| | |
|---|---|
| Tracer gas field monitoring system | 15 |
| Ventilation monitoring and data acquisition system | 25 |
| Sample concentrator | 9 |
| Portable gas chromatograph with photo-ionization detector | 9 |
| Data logging system | 5 |
| Photo-ionization detector, electrometer, and power supply | 4 |
| Magnetic cassette recorder | 5 |

National Bureau of Standards

| | |
|---|---|
| Upgrading of guarded hot plate for testing aerogels in vacuum | 20 |
| Building monitoring equipment | 35 |
| Completion of upgrading of calibrated hot box | 20 |

Oak Ridge National Laboratory

| | |
|---|---|
| Test apparatus for evaluating roof system thermal and moisture transport characteristics under controlled conditions | 720 |
| Environmental test chamber for flat insulation testing | 100 |

Massachusetts Institute of Technology

| | |
|---|---|
| Instrumentation for building model test apparatus | 50 |

Princeton University

| | |
|---|---|
| Humidity measurement equipment | 18 |
| Building energy use monitoring and metering instrumentation | 12 |
| Computational system for building energy use monitoring | 13 |
| Infrared scanner | 29 |

BUILDING SYSTEMS SUBPROGRAM (cont'd)

Princeton University (cont'd)

| | |
|---|---|
| Recorder for infrared scanner | 2 |
| Dedicated computer for infrared scanner system | 14 |

Solar Energy Research Institute

| | |
|---|---|
| Glass processing vacuum oven and edge sealing apparatus | 50 |
| Subtotal | $1800 |

FEDERAL ENERGY MANAGEMENT PROGRAM (FEMP)

| | |
|---|---|
| Equipment and instrumentation to be used by Federal agenices in establishing baselines for planning and monitoring shared-savings projects | 100 |
| Subtotal | $ 100 |

TECHNOLOGY AND CONSUMER PRODUCTS SUBPROGRAM

Lawrence Berekeley Laboratory

| | |
|---|---|
| Plasma Diagnostics Laboratory | 100 |

Oak Ridge National Laboratory

| | |
|---|---|
| Absorption Heat and Mass Transfer Labortory | 260 |
| Heat Pump Breadboard Test Facility | 35 |
| Field Test Data Acquisition Equipment | 205 |
| Subtotal | $ 600 |

| | |
|---|---|
| TOTAL BUILDINGS AND COMMUNITY SYSTEMS | $2,500 |

## TENTATIVE LIST OF CAPITAL EQUIPMENT IN FY 1985 BUDGET REQUEST

### INDUSTRIAL ENERGY CONSERVATION

The FY 1985 budget request includes $4,400,000 for new research equipment to be available in national laboratories or elsewhere to enhance the efforts of the researchers. In some cases the equipment will reside in a contractor facility initially and return to a national laboratory at a later date. The following is a tentative list of the planned allocation of this funding which is subject to change as the analysis of specific needs is completed.

Waste Energy Reduction Subprogram

| | |
|---|---|
| Gas Chromatograph System for evaluation of short life compounds and radicals encountered in evaluation of combustion test operations.<br>Contractor use - Gorham, Lab use- ANL | $150,000 |
| Oxygen Generating Unit for $CO_2$ recovery research project.<br>Lab use - ANL | 100,000 |
| Spectroscopic Instrumentation for $CO_2$ recovery research project.<br>Lab use - ANL | 150,000 |
| IR Radiation Monitoring Equipment for combustion monitoring for $CO_2$ recovery research project.<br>Lab use - ANL | 30,000 |
| Mass Spectrograph for evaluating reaction compounds for chemical heat pump application.<br>Lab use - INEL | 120,000 |
| Non Destructive Test Evaluation System for evaluating the quality and integrity of ceramic heat exchanger components.<br>Lab use - INEL | 150,000 |
| SUBTOTAL | $700,000 |

Industrial Cogeneration Subprogram

| | |
|---|---|
| Slurry Concentration Meter for on-line measurement of coal concentration in coal/water slurries for steam diesel project.<br>Contract use - Thermo Electron, Lab use - ANL | $850,000 |
| Thermionic Converter Emmitter Evaluation System for evaluating work function performance of candidate emmitters.<br>Contractor use - Thermo Electron, Lab use - ANL | 200,000 |
| Slurry Particle Size Optical Evaluator for accurately determining single mode, bimodal, and multi-modal particle size distribution in coal water slurries for the steam diesel project.<br>Contractor use - Thermo Electron, Lab use - ANL | 450,000 |
| SUBTOTAL | $1,500,000 |

## Industrial Process Efficiency Subprogram

| | |
|---|---|
| Reactor Instrumentation Equipment for in-flight combustion of black liquor.<br>Lab use - National Bureau of Standards | $100,000 |
| Prototype Sensor Testing Instrumentation for testing sensors developed by DOE-funded research program.<br>Lab use - National Bureau of Standards | 100,000 |
| Char Bed Furnace for analysis of oxidation and reduction of char under continuous conditions.<br>Contractor use - Institute of Paper Chemistry - Lab use - TBD | 100,000 |
| Laboratory Equipment to support black liquor characterization and combustion projects, including spectro-photometer, refrigerated centrifuge, solids analyzer, viscometer, dionex ion chromatograph and compression testers.<br>Contractor use - University of Maine - Lab use - TBD | 400,000 |
| Measurement and Data Acquistion Equipment for High Temperature Sensing<br>Multi-point recorder for melting furnance, pyrometers for surface temperature measurements, optical dimensional measurement system, ultrasonic equipment and transducers, waveform digitizing oscilloscope, spectrum analyzer, precision mechanical measurement devices.<br>Lab use - PNL | 191,000 |
| Analysis Equipment and Software for High Temperature Sensing<br>Computer to support both data acquistion and analysis; features would include an array processor, real-time memory, and graphics terminal to support imaging and analysis, isometric image processor (this is custom built by PNL to enhance imaging capabilities of the computer system, desk-top computer for analysis and data base management, softeware imaging and analysis packages.<br>Lab use - PNL | 151,000 |
| Materials Characterization Equipment Fourier Transform Infra-Red Spectrometer<br>State-of-the-art spectrometer for surface analysis and identification of compounds and molecules on new ceramics and metals for high temperature heat exchangers and metal producing processes. Spectrometer for MIT materials. Science and Engineering Department initially.<br>Eventual lab use - INEL | 90,000 |

**Equipment for Electrode Development and Current Efficiency**
Major items include a 500 watt $CO_2$ laser, a high temperature controlled atmosphere furnace, raman programmed potentiostats, and supporting diagnostic equipment. Equipment for MIT materials Science and Engineering Department.
Eventual lab use - INEL $128,000

**Electric Arc Furnace Power**
Performance instrumentation for American Iron and Steel Institute. Instrumentation to accurately assess electric arc furnace power utilization. Equipment to be mobile for multiple plant use. Digital furnace data acquisition system. Digital signal analysis and recording equipment. Will be used at various steel plants.
Eventual lab use - INEL 750,000

**Robotic Sampling Mechanism for Molten Steel Analysis**
A semi-intelligent, mechancial robotic device, capable of operating in extremely harsh environments, is necessary to obtain consistent samples for molten metal analyses. Acquistion of a commercial robotic device would substantially enhance the Laser Assistance Steel Sensing (LASS) Project.
Lab use - Los Alamos National Laboratory 125,000

**Echelle Spectrometer**
An echelle spectrometer is a compact and rugged instrument which is particularily suited for multi-element analysis using emission spectroscopy. Incorporation of this instrument into the LASS prototype device would augment the operational capabilities of the field tested system.
Lab use - Los Alamos National Laboratory 30,000

**Improved Laser System**
The spectrochemical methods proposed for molten metal analysis require a laser which vaporizes the sample being studied; higher laser powers increase the rate of vaporization thus enhancing the analytical capabilities of these methods. Such a laser system could be used for analyses conducted in the non-ideal environment of a metal producing plant.
Lab use - Los Alamos National Laboratory 35,000

SUBTOTAL $2,200,000

TOTAL $4,400,000

## ECUT FY 1985 Facilities and Capital Equipment Request

### Facilities

| | |
|---|---|
| Phase zero review and design study of requirements for unclassified laboratory and computational facilities dedicated solely to ECUT. | $600K |

### Capital Equipment

Subprogram: Combustion

| | |
|---|---|
| Two-component LDV (Laser Doppler Velocimeter) signal processors for Engine Lab (Processors and upgraded computer data storage). (Sandia) | $45K |
| Single-shot CARS capability for engine experiments (OMA, spectrometer, wavemeter). (Sandia) | $55K |
| Digitizing Oscilloscope (UC Berkeley). | $13K |
| Two-component LDV capability for pulse combustion facility (Processors, interface, optics, spectral analyzer, 171 Laser)(Sandia) | $85K |
| Pulse combustion upgrade for solid and liquid fuel testing (droplet sizing instrumentation and fuel handling). (JPL) | $65K |
| Multifuel Combustor System (Instrumentation for liquid fuel spray combustion diagnostics).(JPL) | $300K |
| Single-cylinder optical diesel research engine. (Sandia) | $50K |
| Laboratory spray combustion equipment and instrumentation.(Sandia) | $150K |
| OH radical spatial imaging capability for engine knock and future diesel combustion experiments. (Sandia) | $100K |
| Multidimensional imaging capability (Princeton University). | $75K |
| Computer Data Acquisition Hardware (UC Berkeley). | $17K |
| LDV Instrumentation Upgrade for Combustion Bomb (Purdue University). | $25K |
| Instrumentation for Knock Studies (MIT). | $10K |
| Spray Combustor Instrumentation (NBS). | $25K |
| Instrumentation for Combustion Emissions (LBL). | $10K |

Subprogram: Materials Sciences

| | |
|---|---|
| Atom Microprobe for Materials Characterization. (ORNL) | $300K |

| | |
|---|---|
| Special Magnet for Implanting Monovalent Heavy Ion Species. (ORNL) | $50K |
| High Temperature Microhardness Tester. (Historically Black College) | $100K |
| Ion Milling Equipment for Near Surface Region Mateials Studies.(ORNL) | $50K |
| Laser Surface Treatment Equipment for Ceramics.(ORNL) | $100K |
| Non-Destructive Evaluation Multi-frequency Ultrasonic Analyzer To Probe Defects at Ceramic Joints.(Historically Black or Womens College) | $100K |
| Environmental Chamber and Detection Apparatus for Synchrotron Light Source. (Brookhaven National Lab) | $75K |

Subprogram: Biocatalysis

| | |
|---|---|
| Three-Dimensional Color Graphics Molecular Display (Caltech). | $200K |
| Tuneable Laser Flow Cytometers (Caltech, Historically Black College). | $450K |

Subprogram: Tribology

| | |
|---|---|
| Oscillatory, Sliding and Rolling Friction Test Rigs having Environmental Control capabilities and Laser Diagnostics. (ANL) | $125K |
| Gas Chromatograph/Mass Spectrometer. (NBS) | $150K |
| Scanning Electron Microscope for Analyzing Wear Surfaces. (Historically Black or Woman's College) | $75K |
| TOTAL | $3400K |

1 of 2

QUESTIONS FROM THE MAJORITY

| | |
|---|---|
| Question 2: | The Administration has requested no funds for building systems interactions and very little funding for whole building performance R&D, despite strong recommendations for funding in this area in the Carmel Valley workshop report and elsewhere. Please explain the rationale for this decision. What useful research, appropriate to the federal role, could be done in this area with additional funding? |
| Answer: | The FY 1985 budget provides no funds for whole buildings work because we believe it is an area where private architects and engineers and their associations should take the lead.<br>The process from basic research to new buildings involves a chain of connected activities. Basic research leads to component research, which leads to research integration (whole buildings research), which leads to innovative designs, which leads to pioneering new buildings, which leads to post-occupancy evaluations, which leads to information and education programs.<br>DOE has focused its research on the front end of this process as the most appropriate area for Federal support. There are, however, planned activities that support industry efforts in whole building research. These activities include support for performance prediction tools, such as DOE-2 and its planned improvements, the continued support for the Building Energy Guidelines and Standards program, and an expanded technology transfer effort.<br>The Department believes that additional research in this area, particularly in the area of whole building performance R&D, would not be an appropriate Federal role. |

## QUESTIONS FROM THE MAJORITY

Question 3: Please describe and provide a rationale for each of the tasks listed on pp. 46 and 47 under Integrated community energy systems. Were industry and local government officials involved in planning the FY 1985 request in this area? Does DOE have a multi-year plan for research and development related to community systems? If so, please provide two copies for EDA Subcommittee staff.

Answer: The research tasks listed under Integrated Community Energy Systems were selected after discussions with industry, community and utility representatives. Ideas were received from such groups as the North American District Heating and Cooling Institute, International District Heating Association, American Society of Heating, Refrigerating and Air-Conditioning Engineers, U.S. Conference of Mayors, American Planning Association, Rockwell Energy Technology, Geo-Heat Center and others. Ideas were also received from two reports, "RD&D needs of District Heating and Cooling" by Jack Gleason and "Research needs for District Heating Systems" by the International Energy Agency.

The list of tasks is preliminary. We are currently in the process of evaluating each task to determine the research need, DOE role, subtasks and detailed level of effort. In addition, and in parallel, we are in the process of developing a multi-year plan and other program development activities during FY 1984 may alter the tasks on pages 46 and 47 currently proposed for FY 1985 funding.

The following description of each task is based on the preliminary assessment made in FY 1983.

District Cooling. Both utilities and industry have identified district cooling as an area in which DOE community systems should initiate research activities. It is their belief that the contribution of district cooling to energy conservation could exceed that of district heating. DOE's past research effort has focused on district heating. During FY 1984 we will assess the research needs in district cooling and develop a detailed research effort for FY 1985.

Piping and Distribution Systems. The cost of the distribution system can account for up to 75% of the total cost of a district heating and cooling system and, therefore, is a major area which requires research to reduce both material and installation cost. The initial investigation will focus on plastic pipes as alternatives to steel piping because the existing steel piping technology for hot water district heating is to costly to serve low-density heat loads. The technology is not cost-effective for connecting residential areas. The systems generally have to be welded at 30-ft. increments, and this leads to expensive installation. Plastic piping systems have the potential to significantly reduce material and installation costs.

Fully Automated Small Solid-Fuel Combustors. There is a large potential for use of small boilers in district heating and cooling systems in the U.S. Since gas and oil boilers require a minimal amount of staff for operation and maintenance, they are being used. Solid fuel (coal) combustors are not currently competitive with oil and gas units because they require four to five times as much manpower for operation and maintaining as do gas or oil boilers. The requirement for additional manpower is a major impediment to the use of small, solid fuel combustors. Our current plan is to support development of the technology needed by industry to develop a fully automated, clean-buring solid fuel combustor which operates at competitive cost.

Meters and Control Systems. Installation of meters can reduce district heating and cooling systems consumption by 20%. However, current meters are costly and inaccurate. Those for small customers cost over $500. To be cost-effective based on conservation savings, the cost of a meter should not exceed $100. We plan to hold a conference with manufacturers and primary users to review the issues and industry research needs to reduce meter costs, increase the accuracy of meters, and improve overall systems management cost.

Site Design Principle. Research has shown that siting and landscaping choices can affect the micro-climate of spaces between buildings, thereby influencing energy requirements for space conditioning. The project will determine the extent to which these effects are well enough understood to be accurately predicted during the design of building clusters and will evaluate how building site design can effect district heating and cooling systems.

Community Analysis. The research effort will continue to develop analytical tools that can be easily and inexpensively accessed and used by decision makers and energy systems designers. We will also examine current financial arrangement options for district heating and cooling projects and analyze financial and institutional barriers.

Technology Transfer. Workshops, technology assistance to communities and presentation at professional and industry conferences will continue.

## QUESTIONS FROM THE MAJORITY

Question 4: Why were no funds requested for refrigeration systems and combustion heating equipment in the FY 1985 budget request? What on-going activities will be terminated as a result of this decision? If Congress were to appropriate funds in these two areas for FY 1985, what would be the highest priority activities to carry out, in the Department's view?

Answer: No funds were requested for refrigertion and combustion heating research because the private sector is more apt to carry out the needed research in this area than in other building equipment areas. For example, Lennox Corporation has developed a pulse combustion furnace with an efficiency of 95 percent, as well as an air conditioning unit with an advertised EER of 14.

On-going research which will be terminated includes nonazeotropic* refrigerants, ground coupling, novel cycles, commercial building equipment, advanced appliance insulation, equipment-building integration, condensing heat exchanger materials, and wood combustion.

If Congress were to appropriate funds in these two areas for FY 1985, the highest priority activities would be nonazeotropic refrigerants, equipment-building integration, novel cycles, and condensing heat exchanger materials.

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*Nonazeotropic refrigerants boil over at a range of temperatures and are therefore potentially more efficient in refrigerant applications with working loads.

## QUESTIONS FROM THE MAJORITY

Question 5: **What is the rationale for creating a new energy-efficient buildings center rather than working with building industry trade associations and State and local government agencies to disseminate information about energy-efficient buildings? Were NAHB, AIA, ASHRAE, NIBS, or any other building organizations involved in preparing this initiative?**

Answer: The Energy-Efficient Buildings Center is not proposed as an alternative to working with the existing industry trade associations and State and local government agencies. It is primarily designed to enhance the procedure for getting information to these groups and to get it to other relevant groups not now served.

This initiative was developed as a result of trying to determine how information from the Federal R&D programs and information obtained from the private sector, universities, industry research organizations, State governments, and foreign governments (by means of the International Energy Agency) could be more effectively and efficiently assembled, evaluated, and distributed to relevant target groups. NAHB, AIA, ASHRAE, NIBS, and other building industry organizations have been involved in discussions of how to improve this technology transfer activity. Information from these organizations about their information needs as expressed in special conferences and workshops has been considered.

## QUESTIONS FROM THE MAJORITY

**Question 6:** Please explain the rationale for reducing the staffing level from 71 FTE's to 60 FTE's while increasing the budget request for program direction from $2.9 million to $3.1 million.

**Answer:** The reduction of 11 FTE's from FY 1984 to FY 1985 reflects the same overall reduction for staffing under Energy Conservation appropriated programs. These reductions reflect all possible management efficiencies.

The increase of $0.2 million in FY 1985 for BCS program direction budget authority is attributed to increased travel and training. This will help to improve productivity and on-site program monitoring and help to offset the reduction in FTE's. Also, the FY 1985 request includes benefits for former personnel.

## QUESTIONS FROM THE MAJORITY

Question 7: Please explain the source of the $10,077,000 in prior year balances "that are being credited against the energy conservation account." Also, provide details of the $8,000,000 in savings from management initiatives.

Answer: The department is planning to use $10.1 million of FY 1983 unobligated budget authority in the Conservation programs to offset the FY 1985 Congressional Budget Request. These reductions reflect FY 1983 year-end unobligated budget authority which are included in an FY 1984 deferral. The amounts, which are consistent with the current obligational plan for the programs, includes $2.9 million from Buildings and Community Systems, $2.9 million from Industry, $2.8 million from Transportation, $0.5 million from Multi-Sector, and $1.0 million from State and Local.

The $8.0 million reflects projected savings from DOE Management Initiatives. Specifically, savings from Financial Systems Reforms attributed to improved audit measures and similar techniques will permit $8.0 million in deobligations to be used to further offset the FY 1985 Congressional Request.

QUESTIONS FROM THE MAJORITY

Question 8: How does the Industrial Program coordinate its efforts with those of fossil energy in areas of mutual interest such as coal-fired Brayton engines, slagging coal burners and coal-water diesels? How are management decisions and funds allocated between CE and FE in these areas?

Answer: For coal fired brayton engine and coal fired diesels, the industrial program carefully examines in detail the statements of work and the interim and final reports of the prior fossil energy work before establishing the work requirements for its R&D. It interchanges program planning documents at the Branch Chief and Program Manager level. Meetings have been held at the Deputy Assistant Secretary level to coordinate programs. Initial planning is underway for cross utilization of experimental test facilities.

In general, the industrial program in these areas concentrates on developments for cogeneration applications while the fossil energy effort concentrates on fuel based developments in all applications and generally at an earlier stage in the development cycle. Funding requirements are handled separately by the office conducting the activity. Results of the projects are shared.

The slagging coal burner work is a jointly funded Industrial Programs-Fossil Energy activity led by the Pittsburgh Energy Technology Center (PETC). The work is well coordinated by PETC as detailed in a program plan with joint meetings held on the projects included in the program. A memorandum of agreement on the program management was signed by Fossil Energy and the Office of Industrial Programs prior to the program initiation including the funding. Subsequent funding requirements are agreed to by each of the offices.

## QUESTIONS FROM THE MAJORITY

Question 9: Is $3.8 million sufficient to fund all activities required in FY 1985 in conjunction with the thin strip steel casting pilot plant initiative? Please provide a copy of the work statement associated with the RFP for this project. When will an award be made?

Answer: Because the thin strip casting pilot plant contract will not be awarded until late in FY 1984, $3.8 million would be sufficient to fund all activities required in FY 1985. Proposals are due on March 5, 1984. Selection of a contractor is to be accomplished by May 15, and the contract should be signed, after completion of negotiations, by September. Attached are: (1) The Solicitation for Cooperative Agreement Proposals (SCAP); (2) Amendment 1 to the SCAP, which was issued on January 27; and (3) A copy of a January 31, 1984, letter from the Contracting Officer to prospective proposers.

**Department of Energy**
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

January 31, 1984

SUBJECT: Solicitation for Cooperative Agreement Proposals No. DE-SC07-84ID12500, "Energy Efficient Strip/Sheet Casting Technology Development Program - Additional Information"

Prospective Proposers:

The attached executive summary report entitled, "Thermal Analyses of a Concept for Thin Strip Steel Casting (Clad Strip Process)" describes research performed by EG&G, Idaho, Inc. at the Idaho National Engineering Laboratory for the Department of Energy. A patent application has been filed on the described concept and is identified as "Thin Strip Steel Casting" (Ralph L. Sheneman), Patent Office Serial Number 547682. Documentation of the research is not yet complete. If the final report is completed prior to the close of the proposal period, copies will be sent to those who have indicated their intent to submit a proposal. The report will subsequently be made available through the National Technical Information Service in Springfield, Virginia. The following disclaimer applies to the use of any information contained in the executive summary report:

> "This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or processs disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

William C Drake
William C. Drake
Contracting Officer

# EXECUTIVE SUMMARY

# THERMAL ANALYSIS OF A CONCEPT FOR THIN STRIP STEEL CASTING

D. L. Knudson and H. L. Brown

EG&G Idaho, Inc.

Work performed under
DOE Contract DE-AC07-76ID01570

## Introduction

A novel concept for production of thin metal sheet and strip by direct continuous casting has been investigated by the U.S. Department of Energy and a U.S. patent applied for. The concept has substantial energy saving potential over conventional strip/sheet production technology and represents a major step forward, since the expected product thickness falls between the lower limits of continuous casting as now practiced and the upper limits of rapid solidification technology (RST). Surface quality problems associated with some current RST products should be negligible since two strips of the composition being cast serve as integral molds for the molten steel. Product recycling to provide the strip material is approximately 20%.

Conventional strip/sheet production from molten steel proceeds from either an ingot or a section of a continuous-cast billet, with successive hot-working reductions to a thickness suitable for cold reduction and finishing. Either route generally involves reheat and temperature equalization (soaking) steps between reduction operations. The twin-strip approach promises to eliminate essentially all reheat requirements by casting a near-net thickness product which should require only minimal finishing. The energy requirements per ton of finished product are thus reduced substantially, perhaps by as much as 5 x $10^6$ Btu compared with current continuous casting practice. This energy reduction translates directly to an appreciable economic saving. Other economic benefits may also accrue, particularly for new or substantially refurbished strip/sheet production facilities, where both the capital and the operating costs of reheat and hot-working equipment can be avoided. However, no economic analysis of the twin-strip casting concept was performed during this study.

## Concept Description

As previously stated, the concept involves casting molten steel into a mold partially comprised of two parallel metallic strips of suitable composition (normally the same as the molten steel). Edge containment for the molten metal is also provided. During temperature equalization, the hot metal is expected to bond to the strips, which then become an integral part of the product. The casting operation and the initial product cooling take place in an inert gas environment, to minimize oxidation.

Two equipment configurations have been considered. In the first, force-cooled twin rollers maintain product thickness and provide a primary heat sink; product support and supplemental cooling are provided by a large secondary roller and a series of positioning idlers. It must be emphasized that the product is cooled in this manner only enough to permit subsequent handling.

The second proposed equipment configuration uses twin belts, rather than rollers, for heat transfer and product support. Large, force-cooled drive rollers position the twin belts; belt support and partial cooling along the casting span is achieved by idlers or rigid support slabs. Again, only the minimum necessary cooling occurs.

For optimum thermal efficiency, direct finishing is desirable. Limited mechanical working of the hot product, if required, benefits its metallurgical structure while approaching the desired thickness; further thickness reduction by cold working as needed can follow.

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For optimum thermal efficiency, direct finishing is desirable. Limited mechanical working of the hot product, if required, benefits its metallurgical structure while approaching the desired thickness; further thickness reduction by cold working as needed can follow.

### Scoping Evaluation for Concept Patentability

The initial work on the concept was to support a patent application. First, possible physical configurations were examined in the context of expected product cooling and handling problems, and a practical-appearing version was selected. Nominal dimensions and limited process parameters for subsequent work were then established.

Next, an elementary thermal analysis (hand calculations), based on simplified assumptions, was performed. The results of nine different cases appeared to indicate that (1) the process was feasible, and (2) practical strip thicknesses could be produced when using 0.008 in. thick strips for the mold. This strip thickness is commonly used for can stock.

### Independent Review

A detailed review of the concept and the scoping evaluation was performed by an independent consultant, who confirmed the technical feasibility of the concept and identified major technical issues to be resolved for concept development. The consultant concurred with the analytical approach and verified the calculations, but noted the need for computer simulation of the solidification process to examine a broad range of thermal and material property variations.

### Detailed Thermal Analysis, Part I

Following the independent review of the concept and the scoping evaluation, a more detailed computer-based analysis was undertaken to refine the thermal aspects of the concept. All other technical aspects were beyond the scope of the overall investigation.

> Approach: A two-part computer model of this process was developed to permit in-depth analysis of the thermal behavior of such a system. The first part of the model described the molten pool portion of the system where molten steel is poured between the clad; the second part

described the product (consisting of the cast core and clad). Figure 1 shows the primary equipment and its configuration for this process. The thermophysical properties used in conjunction with the model for this analysis were those of AISI-1020 steel, the largest-tonnage material for strip/sheet fabrication.

Tasks: The principal tasks for this analytical effort included:

A. Development of the two-part model incorporating the following process parameters:

   1. Thermophysical properties for the desired steel composition

   2. Depth of the molten pool

   3. Casting roller radii

   4. Product width

   5. Bulk thermal conductivity of the molten pool

   6. Convection heat transfer coefficient from molten to solid steel

   7. Roller coolant temperature

   8. Convection heat transfer coefficient from the product to the surroundings

   9. Radiant emissivity to the surroundings

   10. Initial clad temperature

   11. Initial molten metal superheat temperature

12. Clad thickness

13. Product thickness

14. Product linear speed, in./sec

15. Molten pool boundary layer conductivity

16. Molten pool boundary layer profile

17. Ambient temperature

18. Contact coefficient between the product and the casting and the cooling rollers.

B. Use of the model to analyze the casting process for products in the thickness range 0.064 to 0.125 in. and nominal clad thickness of 0.008 in., and compare the results, assumptions, and method with those for the previous hand calculations.

C. A sensitivity analysis was performed to examine the effects of the last nine Task A parameters (10-18) on the process (without investigation of any interrelationships). For this task, the first nine parameters were fixed at presumably reasonable values based on the logic that their variation would have little effect on the process. Those parameters studied were varied as follows:

| Parameter | Nominal Value | Additional Values Considered |
|---|---|---|
| Initial clad temperature, °F | 500 | 1000, 1500 |
| Initial molten metal superheat, °F | 100 | 200, 300 |

| | | |
|---|---|---|
| Clad thickness, in. | 0.008 | 0.012, 0.016 |
| Product thickness | 0.125 | 0.064, 0.070,<br>0.0775, 0.080 |
| Product linear speed, in./sec | 64 | 32 |
| Molten pool boundary layer conductivity multiplier | 2 | 1, 4 |
| Molten pool boundary layer profile factor | 1 | 0.25, 0.50 |
| Ambient temperature, °F | 500 | 100 |
| Contact coefficient, Btu/hr-ft$^2$-°F | 500 | 100, 2500 |

Results: The two-part model was developed and applied as planned. Examination of results, assumptions, and method used in the hand calculations versus the computer analysis indicated that the assumptions and method for the hand calculations were oversimplified, and therefore, a valid comparison of results from the two methods (hand versus computer calculations) was not possible. For this reason, the documented analytical work exclusively addresses the formal computer-based effort.

Variation of the Task 3 parameters over their stated ranges revealed that, for most of these parameters, the effects on the process are minimal. A definite interrelationship does exist between product thickness and clad thickness (hereafter referred to as the molten-to-solid ratio), and has an appreciable influence on the overall process. The effect is not uniform for a given ratio as total product thickness is varied, since the heat removal requirement changes while heat transfer capability remains constant.

Calculations made with the model indicated that a 0.125 in. thick product cannot be cast with 0.008 in. clad because of clad failure by melt-through. A clad thickness of 0.012 in. is required in casting a 0.125 in. thick product to prevent melt-through although the minimum tensile strength available for product handling during casting may be marginal in the proposed configuration. Product integrity and what was assumed to be more than sufficient minimum tensile strength during casting can be achieved using 0.016 in. clad to cast 0.125 in. thick strip. When the clad thickness was held at 0.008 in., the maximum product thickness which can be cast without clad melt-through was found to be 0.080 in. The current data base, however, is insufficient to make a prediction of product thickness versus clad thickness for lesser or greater product thicknesses, and the limited scope of this part of the analysis precluded further determinations.

Plots of product thickness versus clad thickness and molten/solid ratio are presented in Figures 2 and 3, respectively. The nonlinear behavior with changing product thickness is apparent in both plots. In Figure 2, the solid curve represents a molten/solid ratio of 4.2, calculated from the minimum 0.012 in. clad thickness required in casting a 0.125 in. product. The broken curve connects the two data points which identify minimum clad thicknesses for 0.125 in. and 0.080 in. product thicknesses. The physical concept requires that this curve also pass through the origin. Any combination of clad thickness versus product thickness which lies above the broken curve could be cast without clad failure by melt-through. The minimum tensile strength encountered during casting of a particular clad/product thickness combination increases with distance from the broken curve.

Figure 3 shows more dramatically, for the same data, how the molten/solid ratio deviates from a constant value. In a practical sense, however, the trend of this curve for near-zero product thickness is uncertain and not meaningful. In this case, combinations of clad thickness versus product thickness which lie below the broken curve could be cast without clad failure by melt-through.

It should be noted that some of the legends on these plots have been abbreviated; "minimum clad thickness" is the minimum required for casting without clad melt-through, and "max m/s ratio for product thickness" is the maximum molten/solid ratio for casting a product of a given thickness without clad melt-through. A fine-scale evaluation of the process as a function of time indicated that partial (surface) melting of the clad would occur in any case, a desirable state in terms of achieving a good metallurgical bond between the solidifying metal and the clad.

### Detailed Thermal Analysis, Part II

An alternate equipment configuration (Figure 4) proposed for the twin-strip casting concept necessitated an additional thermal behavior analysis to determine the effects of the equipment changes on product temperature equalization and heat transfer to the equipment.

The configuration change did not drastically alter the basic problem nor require modification of the existing model. The thermophysical and thermal property data already at hand from the earlier work were readily utilized. The principal equipment configuration change involved the use of twin belts (rather than rollers) for casting support. The belts studied were either 2 1/4 Cr 1Mo or Type 304 stainless steel. Either small support rollers or (optionally) a rigid support slab were used beneath the load-carrying portion (casting span) of each belt. One portion of the results of this analysis relates to maximum and minimum average service temperatures experienced by the two belt materials. This information is of major value for subsequent design engineering.

Case 1 assumed a Type 304 stainless steel support belt and support rollers beneath the casting span, while Case 2 substituted a 2 1/4 Cr-1Mo belt. (Belt thickness for the analysis was determined for an essentially infinite mechanical fatigue life from ASME Boiler and Pressure Vessel Code compilations). Use of the stainless belt was found to represent a more severe condition, for both temperature gradients and maximum belt and product takeoff temperatures. Case 3 substituted rigid support slabs for the casting span support rollers, with appreciable reduction of the Type 304 belt temperature gradient and maximum temperatures.

Since formal data were not available, thermal properties of stainless steel were extrapolated over a nominal 200 to 300°F interval, and 2 1/4 Cr-1Mo thermal properties and yield strength data over a nominal 400 to 500°F interval. However, the availability of firm data for AISI-1020 steel for comparison purposes reduces errors from this source. Other factors and modeling assumptions (identified in the report) seem to have more of an impact on the results than these extrapolations.

## Conclusions and Recommendations

The conclusions from these analyses are:

### Part I - Wheel Casting

1. Continuous casting of thin-strip steel in the manner proposed is feasible from the thermal analysis standpoint. Changes in process equipment configuration and/or other non-thermal factors could affect these results and would have to be examined on a case-by-case basis.

2. The analysis was based on the best available thermophysical property data for the material considered. Since these properties are measured values, as used by the steel industry, it is felt that they are acceptable for use in this study. For certain complex thermal phenomenon associated with the process, values were assumed and then bracketed to determine their effect on the analysis. The assumed values appeared reasonable, since the results were essentially insensitive to variations of these values.

3. Further use of the thermal model in its present form appears desirable in two areas:

First, the maximum product thickness should be determined for additional clad thickness values outside the current 0.008 to 0.016 in. range. The benefits from this effort would be (1) An advance correlation of clad and product thickness dimensions within the range of anticipated continuous strip casting product development and (2) An effective means for guiding such development.

Second, the model should be used for a pre-operational check on a prototype continuous casting system, using actual design parameter values wherever possible. Such systems are now being studied under DOE contract. The proposed check could, at no physical risk, identify potential problem areas of operation. An additional benefit would be at least partial verification of the model through experimental investigation.

4. The model could also be expanded and refined economically to support evaluations of other systems such as those considered in the DOE-sponsored thin-strip casting development program now in progress. The primary benefit of this application would be an analytical check of other system designs, plus a cross-comparison of models where the contractor has developed his own process model.

Part II - Twin Belt Casting

- Casting 0.080 in. thick strip using 0.008 in. clad strips in the manner proposed is thermally feasible.

- Belt heat capacitance is an important consideration for minimizing thermal stress effects.

- The optional heat slabs appear more effective than the idler rollers in reducing temperature effects in the belts.

- This equipment configuration promises substantially fewer problems with maintaining integrity of the solidifying product than the previous (all-roller) configuration.

## Recommendations for Further Work on the Twin-Strip Concept

The following additional efforts are considered necessary for further development of this concept:

1. Experimental program design to verify analytical results

2. A laboratory-scale investigation to confirm concept feasibility.

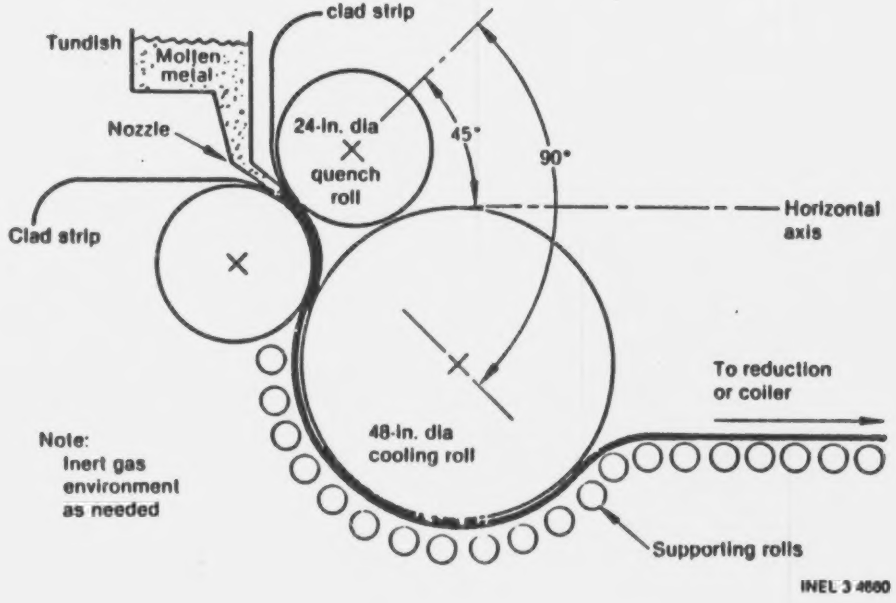

Tundish
Molten metal
Nozzle
clad strip
Clad strip
24-in. dia quench roll
45°
90°
Horizontal axis
48-in. dia cooling roll
To reduction or coiler
Supporting rolls
Note: Inert gas environment as needed
INEL 3 4660

Figure 1. Proposed continuous thin-strip casting equipment configuration (not to scale and not based on calculated thermal requirements).

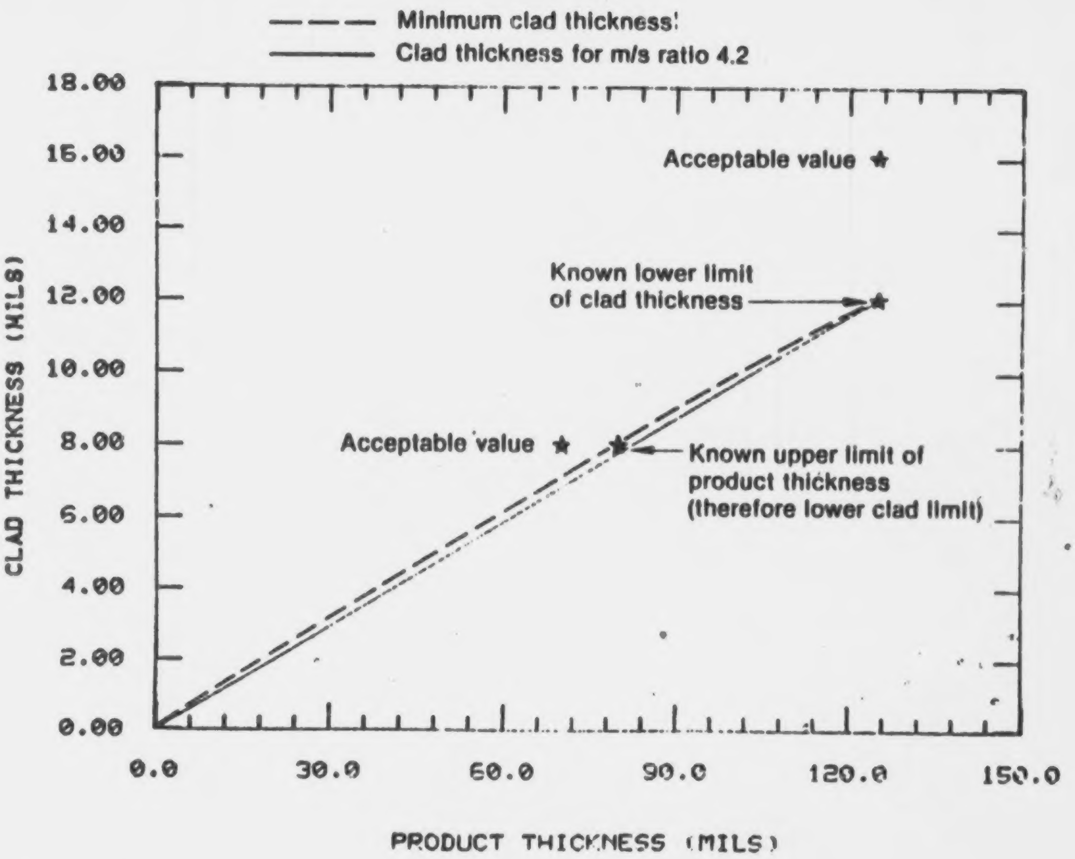


Figure 2. Analytically derived product thickness versus clad strip thickness for continuous cast AISI-1020 steel strip.

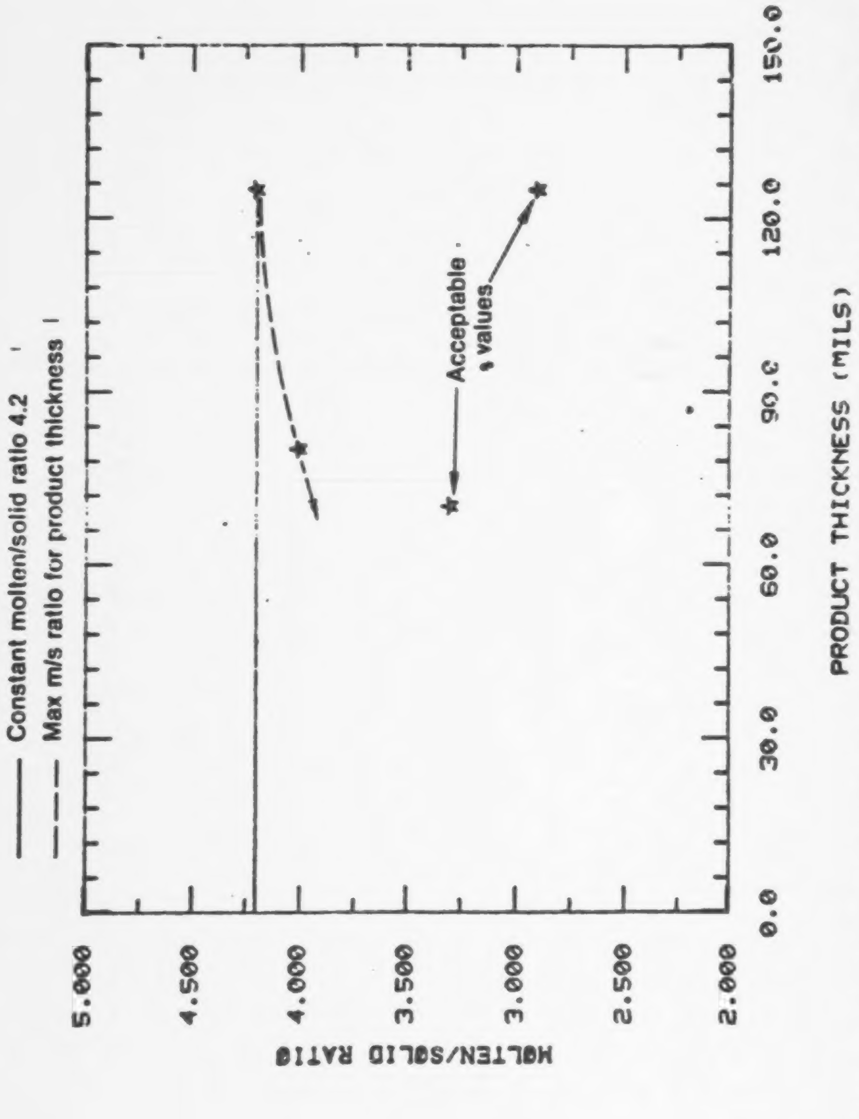


Figure 3. Analytically derived product thickness versus molten/solid ratio for continuous cast AISI-1020 steel strip.

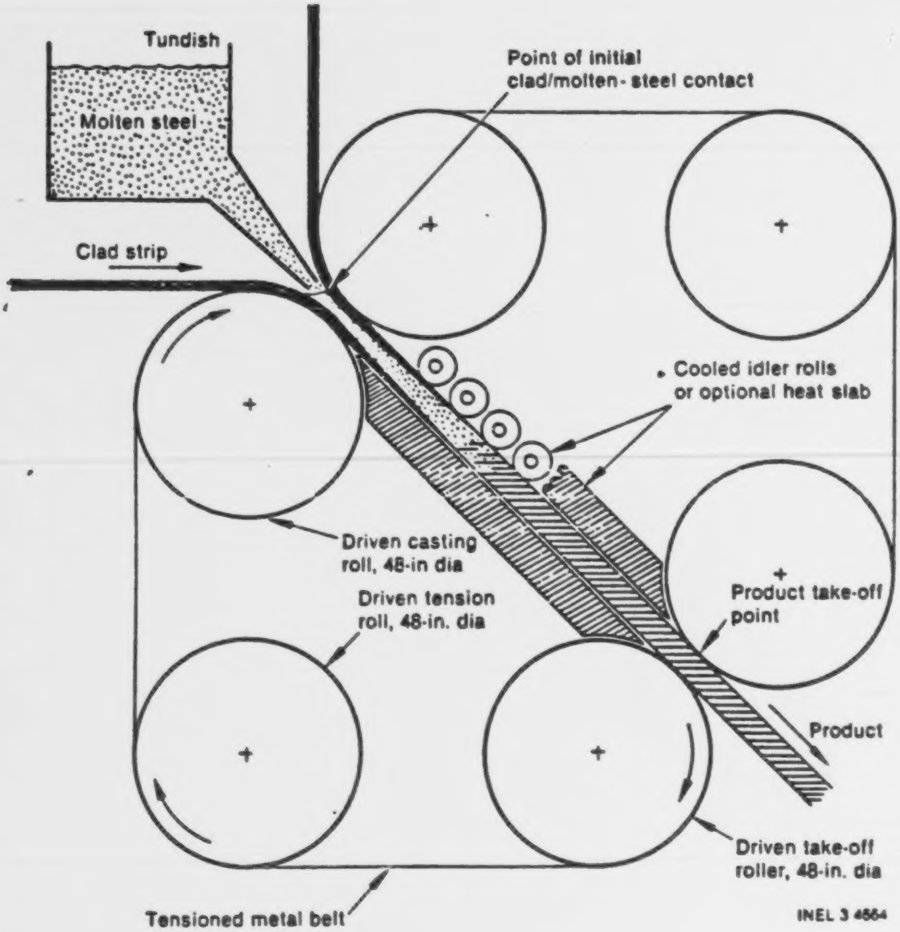
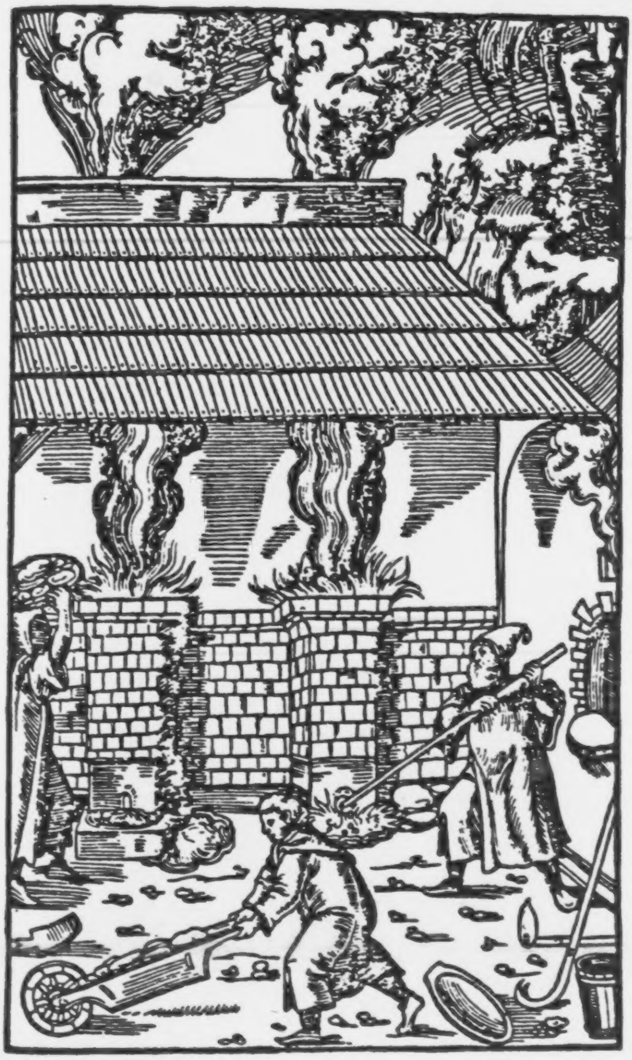

Tundish
Molten steel
Clad strip
Point of initial clad/molten-steel contact
Cooled idler rolls or optional heat slab
Driven casting roll, 48-in dia
Driven tension roll, 48-in. dia
Product take-off point
Product
Driven take-off roller, 48-in. dia
Tensioned metal belt
INEL 3 4564

Figure 4. Proposed belt-supported thin-strip steel casting equipment configuration (not to scale). Belt orientation shown 45° from vertical.

SOLICITATION FOR
COOPERATIVE AGREEMENT
NUMBER DE-SC07-84ID12500

# ENERGY EFFICIENT STRIP/SHEET CASTING TECHNOLOGY DEVELOPMENT PROGRAM

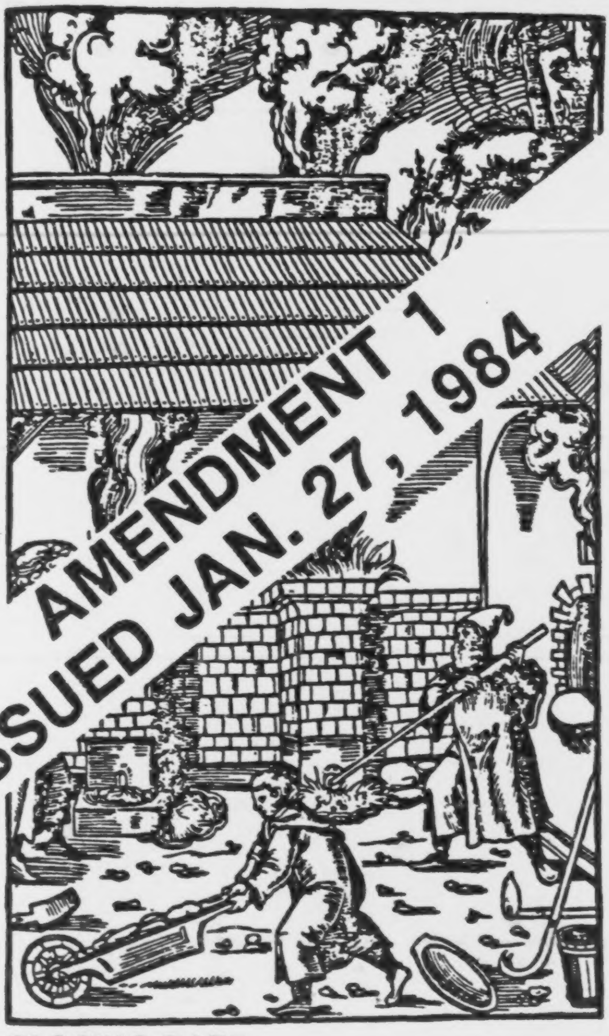


CLOSING DATE
MARCH 5, 1984

DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE

SOLICITATION FOR
COOPERATIVE AGREEMENT
NUMBER DE-SC07-84ID12500

# ENERGY EFFICIENT STRIP/SHEET CASTING TECHNOLOGY DEVELOPMENT PROGRAM



AMENDMENT 1
ISSUED JAN. 27, 1984

CLOSING DATE
MARCH 5, 1984

DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE

## QUESTIONS FROM THE MAJORITY

Question 10: Why have funds for national laboratory support been reduced from FY 1984 levels in the FY 1985 request? What support activities will be curtailed or eliminated as a result of this reduction?

Answer: This question is apparently related to the key activity called "national lab support" on page 67 of Volume 7 of the budget. This item, more properly, would be titled "national labs and other support" and includes support services contractors as well as project management support at national laboratories.

A competitive solicitation for four areas of support services is near issuance within the Department and, considering the time required to review proposals and negotiate contracts, it will be late in FY 1984 before these contracts will be completed. Therefore, FY 1984 funds will be adequate for these services through FY 1985. Therefore, there will be no elimination of support activities.

## QUESTIONS FROM THE MAJORITY

Question 11: **Will any separations research projects be terminated before completion as a result of budget reductions in this area? Which projects will be terminated and what are the FY 1985 funding requirements to continue them?**

**Answer:** A total of ten projects for various membrane separation concepts were undertaken in FY 1983 based on responses from a competitive solicitation. These were all conceptual and required laboratory experimentation and analysis to determine feasibility. During FY 1984, based on results achieved, it is expected and planned that some of these will be discontinued and the more promising will be funded through completion. It is currently too early in the program to identify which of the efforts will emerge and continue.

QUESTIONS FROM THE MAJORITY

Question 12: **Please describe the proposed national information center for industrial conservation technology and describe the rationale for its creation. What funding level is requested for the center in FY 1985?**

**Answer:** The rationale for creation of the center is to provide a clearly identified focal point for assistance to industry in identifying and utilizing technical information, case studies and R&D results and developments related to specific industrial conservation needs and questions.

The center would utilize and build on existing DOE data bases and technical information capabilities including: the Technical Information Center (and the bibliographic services available through TIC); relevant case study materials developed by the Energy Analysis and Diagnostic Centers (EADC) Program and the American Consulting Engineers Council (ACEC); and R&D progress reports. Working closely with interested trade and professional associations, various outside sources of information would be considered for inclusion.

Funding for this project, which is still in the conceptual stage, for FY 1985 is approximately 1 million dollars, including developmental costs.

## QUESTIONS FOR THE MAJORITY

Question 13: Why are no funds requested for alcohol fuels in the alternative fuels utilization sub-program area? Will any projects be terminated before completion as a result of this budget request?

Answer: A comprehensive data and technical information base has been generated on the use of alcohol fuels (blended and neat) in spark ignition engines. Comparable information for diesel engine applications has been generated to the extent required for the potential utilization that is likely to develop. Projects addressing fundamentals of the two remaining problem areas, lubrication/wear and cold start, are expected to be completed with FY 1984 funds. Activities on use of reformed methanol are expected to reach a point in FY 1984 that is commensurate with industry's current views on the benefits perceived for using this fuel. It is expected that these changes in DOE programs in FY 1985 will not have any effect upon private sector research and development in the use of alcohol fuels in spark ignition engines. No DOE projects will be terminated before completion as a result of this request.

## QUESTIONS FROM THE MAJORITY

Question 14: Transportation and ECUT . DOE has requested $9 million for materials research in transportation (ceramics plus advanced materials) and $6 million for materials research in ECUT. It also has requested a large increase in materials research in basic energy sciences. How do the conservation materials program initiatives differ from each other and from those in basic energy sciences? How does the Department insure that no overlap takes place in research in this area?

Answer: The DOE/BES Materials Sciences Program in Energy Research supports fundamental research that is unfocused as to end application, e.g. studies on hydrogen bonding of selected metal hydrides. The Energy Conversion and Utilization Technologies (ECUT) research on materials builds on the fundamental work in BES and applies this new knowledge to crosscutting applications not known to those scientists in the fundamental research community. The materials R&D in transportation (OVERD) is highly focused on one specific transportation application; it is developmental with less emphasis on research. ECUT does not develop materials; rather it matches the end-use sector needs with the advances being made in fundamental research and provides enough additional research to move the emerging technologies into the end-use sectors where development occurs for their specific needs. Thus, ECUT plays a most important role in bridging the gap betweeen unfocused research and highly focused hardware development.

Lastly, the DOE materials programs coordinate their activities to avoid duplication of effort through the Energy Materials Coordinating Committee (EMaCC) chartered by the Office of the Director of Energy Research. EMaCC consists of representatives of all DOE programs (including BES, OVERD and ECUT) having materials research components and meets monthly to review materials aspects of each program. For FY 1983-84 the EMaCC chairman is the ECUT Materials Sciences Program Manager.

## QUESTIONS FROM THE MAJORITY

Question 15: ECUT . The Department has proposed a three-fold increase in materials sciences in FY 1985. What is the rationale for such a rapid scale-up? What would be lost if the planned program expansion were phased in over a two or three year period?

Answer: Over the past two years, the ECUT has supported thorough reviews of the developments and advances in materials and diagnostic equipment now available to change for the good the atomic structure of materials. These findings are now at the point where speedy application of this knowledge to energy saving uses is both timely and justifiable. With the requested budget the materials research in ECUT can finally reach the state needed to pull the new and emerging materials knowledge into the mainstream of useful, practical applications in the energy consuming sectors.

The past decade has seen a veritable explosion of revolutionary techniques to probe the basic structure of materials right down to the atomic structure in order to determine how the atoms are bound together. This instrumentation which DOE/BES has put in place at the national laboratories is unique and can give U.S. industry a marked advantage over foreign competition. Until now, this $450 million worth of instrumentation has been used primarily for academic research or for applications in the DOE weapons program. It is now perceived by applications scientists that this wealth of instrumentation along with the enormous computational capabilities of supercomputers in these labs is at a state to allow the resolution of materials problems of a practical nature.

QUESTIONS FROM THE MAJORITY

Question 16: ECUT. Much of the work proposed for FY 1985 on long range ordered alloys and intermetallic compounds, physical chemistry of inorganic non-metallic materials and materials structure and design appears to be of a basic research nature. Why is it not being transferred to the basic energy sciences program?

Answer: Because the research involved requires an interdisciplinary approach (Materials by design will require interdisciplinary teams composed of chemists, mathematicians, computer scientists, physicists and mechanical engineers.), it would be difficult if not impossible to conduct such a focused research program in the Basic Energy Sciences Program. In other words, while this research is on the interface between BES and ECUT, it would have a tendency to fall between the cracks of the Materials Sciences and Chemical Sciences programs. Moreover, much of what is now being researched by ECUT in the areas cited above originated from the Basic Energy Science programs and it has been stressed to ECUT many times by BES that research flows take place in only one direction from BES to ECUT and not the other way around. This research is seen by BES as being simply too applications oriented for BES support.

The ECUT approach will be to select one specific (and representative) research problem such as the nature of the bonding at the grain boundaries in nickel aluminide ($Ni_3Al$) and to attack the problem with any and all experimental and theoretical (models) tools which make scientific sense to use and to solicit competitively the researchers who will carry out each aspect of the research. In this way, the somewhat meandering nature of research is cut short and results are available much sooner for conservation applications. The output of the example cited would permit a rational approach to making other members of the aluminide family e.g. iron and magnesium alumindes ductile instead of the cut and try approach which is necessary presently.

## QUESTIONS FROM THE MAJORITY

**Question 17:** ECUT. Please explain the rationale for the three- and four-fold increases proposed for catalysis and biocatalysis and wear testing, and tribological coatings and innovations? What would be the impact on the programs of reducing the rate of growth?

**Answer:** For the past three years, the funding in the Energy Conversion and Utilization Technologies (ECUT) Catalysis/Biocatalysis program has been used to establish an appropriate research agenda and suitable research plan for a major effort in bioprocess engineering. Preliminary research efforts to date have been focused on using new biotechniques (recombinant DNA) in the production of bulk chemicals. In a recent OTA report on Commercial Biotechnology (February 1984), bioprocess engineering was cited as one area in which there is need for further research. In FY 1985, ECUT will concentrate on the production of high volume (energy intensive) chemicals from feedstocks other than petroleum and/or natural gas. ECUT has developed a research plan and agenda to establish the necessary technology base for the design and scale-up of large biochemical production plants required for the production of bulk chemicals. The increase in funding is required to properly implement the ECUT plan to perform the research on the major problems identified in bioprocess engineering.

Friction and wear research, which concentrates on screening tests of ceramic materials, is needed to understand the basic mechanisms of friction and wear of these materials. They are not understood today. As one important aspect of this work, these tests will provide the technical underpinning to the Office of Vehicle and Engine R&D (OVERD) testing of ceramic piston rings in single-cylinder engines, the basis for OVERD adiabatic diesel engine research. Friction and wear testing of dissimilar ceramics is also vital to the industrial sectors where ceramic parts will be increasingly used to attain higher operating temperatures than possible with conventional metal ones. The cross cutting nature of this research for the transportation and industrial sectors requires the increase in funding that has been requested.

The request for increased research on tribological coatings is necessary because this research could effect significant energy savings in the industry sectors where precision tooling is a necessity and extreme operating conditions are the norm, such as in the high-technology and defense industries. Harder coatings on machine tools enable such tools to operate at higher temperatures, drill more precisely, produce less waste, and last many times longer than other coated tools.

Research in this field would be conducted primarily by a consortium of university and industrial partners,an ideal technology transfer situation in which results of the work could be quickly translated into a commercially viable technology. If funding were reduced for the tribological coatings research from what is perceived as the beginning of a critical mass, then it is entirely possible that the energy saving benefits which this work could provide would be delayed for several years.

The funding request for innovation research is larger for FY 1985 because of the need to continue and to enlarge a successful program that had begun to stimulate others to think creatively about Government research. The flexible formula developed in the pilot program harvested new ideas from an historically black university, small businesses, a minority firm--groups who can easily be left out of the larger, more rigorous procurements of formal programs. The pilot program has provided options at a low level of obligation to the Conservation end-use sectors and has helped to counter the natural tendency to feel that all the really innovative ideas in a particular field have already been identified.

Reduced funding would diminish this source of concepts for subsequent funding by end-use sector offices and would hamper these organizations outside the mainstream of Federal funding in making valuable contributions..

## QUESTIONS FROM THE MAJORITY

Question 18: How much of the $3.4 million requested for capital equipment will be devoted to "planning and design of early phases of building a new unclassified research facility...in support of the ECUT program"?

Answer: Of the $3.4 million requested for capital equipment in FY 1985, $0.6 million will be devoted to "planning and design of building a new unclassified research facility...in support of the ECUT program."

## SOLAR ENERGY

### QUESTIONS FROM THE MAJORITY

Question 1: Please explain the $10,052,000 in "undistributed" funds and the $32,300,000 in savings from management initiatives in the table on p. 18 of volume 2 of the budget books. Is a deferral of $10,052,00 planned for FY 1984? What will be in it?

Answer: The $10.052 million is FY 1984 unobligated budget authority will be used to offset the FY 1985 Congressional budget request. The $10.052 million is included in an FY 1984 deferral (Deferral No. D84-39 transmitted to the Congress in a February 1, 1984 message from the President) and included $7.4 million for Solar, $0.6 million for Geothermal, $0.3 for Hydropower, and $1.8 million for Electric Energy Systems and Energy Storage.

The FY 1985 Congressional budget request for Renewable Energy programs reflects savings of $9.5 million in budget authority resulting from implementation of various management initiatives. These initiatives, which are described below, are designed to improve the efficiency and effectiveness of Departmental management systems and to place the Department's financial systems on a more business-like basis. Implementation of these initiatives will not only improve current Departmental operations, but will hold out the possiblity of additional savings in future years.

These management initiatives for Renewable Energy programs reflects the first implementation efforts of the Department with regard to recommendations contained in various studies of Departmental operations, including the President's Private Sector Survey on Cost Control (the Grace Commission), and the Federal Laboratory Panel of the White House Science Council (the Packard Report), as well as the

Administration's program of improved management systems known as Reform 88.

The $9.5 million in estimated savings in Renewable Energy programs includes $8.0 million which is attributed to Financial Systems Reforms. This initiative will save $4.0 million in FY 1984 and an additional $4.0 million in FY 1985 through improved management of the deobligation of multi-year funds. Deobligations may occur due to contract close-out, contractor defaults, or other instances of contractual dollar reductions, such as cost disallowances based on audit results. Under this initiative, deobligations will be reported and evaluated to determine whether or not the funding should be retained in the program area where it was originally appropriated. If it is determined that there is no compelling reason to retain these funds in that program area, they will be deferred, if necessary (i.e., FY 1984 and previous years funding), and used to offset budget authority in FY 1985.

The remaining $1.5 million in estimated savings results from the Procurement Reform management initiative. This effort is projected to save $0.5 million in FY 1984 and an additional $1.0 million in FY 1985 through actions designed to improve the utilization and administration of the procurement system. Specifically, increased use of contract audit support by the Department's Inspector General during contract administration to expand audit coverage and increase recoveries.

The $9.5 million in projected savings from Financial Systems Reforms and Procurement Reform for Renewable Energy programs will be used to offset the FY 1985 request. Savings from other management initiatives have already been calculated into the request. For example, the budget request assumes additional savings of $1.15 million for Administrative Process/Field Structure ($1.0 million) and Procurement Reform ($0.15 million).

The $1.0 million reflects savings resulting from improved management of government owned, contractor operated (GOCO) facilities. This initiative involves improved utilization of private sector business practices by GOCO contractors through reduced procedural controls and heightened reliance on policy issuances and performance evaluation by the DOE Operations Offices.

The $0.15 million in Procurement Reform Savings results from expanded use of private sector contractors for accomplishment of commercial and industrial activities under OMB Circular A-76.

## QUESTIONS FROM THE MAJORITY

Question 2: Solar Building Energy Systems. Please explain the rationale for the sizeable reductions proposed in systems simulation and analysis; daylighting and resource characterization; heat transfer; passive cooling systems research; performance monitoring and evaluation and design tools and technology transfer. Please explain how these reductions are consistent with the recommendations of the Carmel Valley workshop. What activities would be carried out in these areas if Congress appropriated sufficient funds to restore them to their FY 1984 levels?

Answer: Research activities which can effect the control of solar gain, light admittance, and heat loss were among the highest priority recommendations of the Carmel Building Energy Research Workshop. The proposed budget for the Solar Buildings Energy Systems program places a primary emphasis on aperture and thermal storage materials research which responds appropriately to the recommendations of the Workshop. In so doing the Solar Buildings Energy Systems program has gained a research thrust and momentum of activities which, according to the Carmel Valley Workshop, can result in a high probability of success, and very substantial energy savings and peak load reductions.

It should be noted that Solar Buildings Energy Systems is one of several solar energy programs, each one of which is aiming to help the U.S. private sector in advancing a solar technology as a competitive energy supply option. Likewise, Solar Buildings should be considered in the context of priorities of the overall solar energy budget request and the need for the Federal government to exercise budget restraint.

## QUESTIONS FROM THE MAJORITY

Question 3: Why were no funds requested for systems experiments? Who will operate the RES's and collect and analyze data from the PRD's in FY 1985? Why has flat plate collector research been cut from $7.5 million in FY 1984 to $4.5 million in FY 1985?

Answer: Funds for systems experiments were not requested because the primary objectives of these experiments, most of which were started in 1979 and 1980, have been achieved. The photovoltaic program has conclusively demonstrated that a photovoltaic system can be designed and operated in such a way as to deliver a.c. electricity that is compatible with and of the same quality as electric utility power. In addition, the systems experiments showed that a variety of modules, including concentrator modules, successfully work to provide reliable power. It is probable that in FY 1985 the Residential Experiment Stations (RES's) will be continued under private and state funding. It is also expected that the "PRDA" intermediate size experiments will be operated by the site owners such as Lea County Electric Cooperative, Beverly High School, and others, and that data will be collected and analyzed by the Electric Power Research Institute and shared with the photovoltaic community. The photovoltaic program will provide technical consultation and loan of data collection equipment.

2

There have been several development in the flate plate collector area which enable the continuation of research at a lower level. Progress in solar cell efficiency advancement has been attained by several processes, for example, liquid applied dopant cells have reached 15% average lot efficiency for 20 $cm^2$ cells and several 18% efficient 4 $cm^2$ solar cells were made by ion implantation. Because of these and other results industry is providing a larger fraction of cost sharing on R&D contracts, requiring less federal expenditure in flat plate collectors.

## QUESTIONS FROM THE MAJORITY

Question 4: The FY 1985 budget request appears to deviate significantly from the Five Year Plan submitted to Congress last year, both in funding level ($64 million/year vs. $47.5 million) and support for collector and systems R&D. Please explain the rationale for this deviation. Can the goals of the plan be achieved with the funding levels proposed in the budget?

Answer: The resource requirements provided in the Five Year Plan are estimates only. Actual year to year needs are based on progress as well as being heavily influenced by industry cost sharing on government contracts and privately funded research and development. For FY 1985, it is estimated that all sources of funding when combined will result in total photovoltaic research expenditures in excess of $100M. At this level of effort, the 1985 milestones are expected to be met. As explained in question #3, the area of collectors and systems research show decreased support because of completion of work in single crystal silicon and wrap up of systems experiments work.

QUESTIONS FROM THE MAJORITY

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|---|---|
| Question 5: | Are funds requested to continue the block purchases and module testing activities at JPL in FY 1985? If not, why not? |
| Answer: | Funds were not requested to continue the block purchase program at JPL, however funds are requested to continue module testing to determine and correct generic module lifetime limiting failure modes.<br>The Block V program, the most recent of the block purchases, was begun late in FY 1981 with a module design phase. Procurement of modules resulting from these designs should be complete before the third quarter of FY 1984 is over and design validation testing should be complete this FY.<br>The PV division believes that due to the complexity of a block purchase this activity should only be undertaken to validate major five year plan flat plate collector milestones like the FY 1988 goal of a 15% efficient, thirty year lifetime module that can be made for $90/square meter. For this purpose a FY 1985 block purchase is premature. |

QUESTIONS FROM THE MAJORITY

Question 6: What is the status of the PON for Small Community Experiments #1 and #2?

Answer: The Small Community Solar Experiments Program Opportunity Notice (PON) was released on December 30, 1983. The PON provides for separate awards to design, construct, and operate for one year a 100 KWe dish electric system at each of two sites, Osage City, Kansas and Molokai, Hawaii. These cost-shared projects will use either Rankine, Stirling, or Brayton engine technologies. On January 18, 1984, a pre-proposal conference was held in Albuquerque with fifteen prospective bidders. Closing date for receipt of proposals is February 29, 1984. It is anticipated that contract awards will be made in August, 1984.

QUESTIONS FROM THE MAJORITY

Question 7: What is the Department's assessment of the likelihood of the Carriza Plains or Solar 100 powerplants being built, assuming the Federal solar business tax credits are not extended by Congress? Assuming they are? If these plants are not built what will be the consequences for the central receiver industry? Are there any other actions the Federal government could take to assist in commercializing this technology?

Answer: The fact that two industry groups are seriously attempting to put together the technical and financial packages to construct solar central receiver power plants is concrete evidence of the remarkable progress which has been made in this renewable technology. In 8 years, the concept has progressed from a scientific curiosity to a serious candidate for supplying electrical energy. Whether these projects will be built depends on a number of economic and technical factors which are, at present, in a delicate balance. A shift in any major factor could be decisive regarding construction. However, the likelihood that industry can attract full financing for these two plants without tax credits appears low.

Even if the tax credits are extended through 1990, a probability of construction of either or both plants remains low unless actions favorable to the sponsors are taken by the California Public Utility Commission. Also the satisfactory formation of venture capital to finance the construction, with adequate guarantees of performance, must be realized in the near term. These are difficult but achievable hurdles.

If these plants are not built, a stretch-out in commercialization of central receiver power plants can be anticipated. However, the Department's R&D programs directed toward reducing technical risk and cost reduction combined with increased emphasis on technology transfer are expected to be adequate in assisting industry in commercializing solar thermal technology.

## QUESTIONS FROM THE MAJORITY

Question 8: The Department has proposed significantly increased funding for production-related research and decreased funding for conversion-related research in the FY 1985 request. What is the rationale for this change in emphasis? Is there sufficient funding in the biochemical conversion request to carry out all activities formerly carried out by the alcohol fuels, municipal waste and biomass programs? What activities, if any, have been discontinued in this area?

Answer: The Energy Research Advisory Board (ERAB) recommended that the Federal biomass program achieve a sharper focus and greater balance between feedstock development and conversion efforts, with highest priority for feedstock development. The Department's request provides for enhanced activities for short rotation woody crops and a significant increase over the FY 84 appropriation for feedstock production of aquatic and herbaceous crops. There is sufficient funding in the biochemical conversion request to carry out the ongoing programs in alcohol fuels, municipal waste and biomass energy. In FY 85, biochemical research in the anaerobic digestion of feedstocks will be reoriented from homogeneous biomass to focus on heterogeneous municipal waste feedstocks. While consideration is being given to phasing out systems research in biological hydrogen production, the Department will continue to support basic research in this and other hydrogen research areas elsewhere in DOE. These adjustments conform with the ERAB recommendations and indicate the Department's commitment to improve the focus and overall R&D framework of the Federal biofuels program.

## QUESTIONS FROM THE MAJORITY

Question 9: What is the rationale for the proposed reduction in funding for the biomass regional programs in the DOE FY 1985 budget request? What is the status of the Northeast and Great Lakes regional biomass programs?

Answer: The Coalition of Northeastern Governors and the Council of Great Lakes Governors are implementing biomass energy programs in their respective regions.which include grants to the states for cost-shared activities, regional resource assessments and the development of regional biomass plans. The Department's FY 85 request provides the funding necessary to maintain the momentum of the regional biomass programs. The Department also recognizes the prior year start-up costs for the regions and believes that, as the programs mature, the private sector can assume a more direct role in the introduction of biomass technologies.

QUESTIONS FROM THE MAJORITY

Question 10: What are the FY 1984 funds required to close-out the Mod-5A program? What does the Department propose to do with unexpended funds from the FY 1984 Mod-5A budget allocation?

Answer: FY 1984 funds in the amount of $1.5M committed to the Mod-5A contract prior to GE's decision to pull out, are sufficient to complete key testing already underway and phase-out the contract with final reports. We are proposing to defer to FY 1985, $3M of funds originally planned for the Mod-5A contract. We are negotiating with Boeing on the Mod-5B in an attempt to reach an acceptable costsharing position. We will advise Congress of our intentions on the Mod-5 program, probably by the end of March.

## QUESTIONS FROM THE MAJORITY

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| Question 11: | What is the Department's position on cost-sharing for the Mod-5B? Has DOE set a date by which Boeing must produce a firm cost-sharing proposal or have the Mod-5B program terminated? |
| Answer: | We believe industry/government cost-sharing is essential to the continuation of the Mod-5B. In January 1984 Boeing informed DOE that it would continue to negotiate for a cost-sharing effort, but not to the extent previously planned. Boeing is now developing a scaled-down cost-sharing proposal. Upon receipt and review of the proposal, we will advise Congress of our intentions regarding the Mod-5 program. We anticipate that this could occur by the end of March. Currently the plan is to continue the Boeing effort if adequate cost-sharing can be achieved. |

QUESTIONS FROM THE MAJORITY

Question 12: Please explain the rationale for the large increases proposed for aerodynamic and structural research. What would be the consequences of delaying or slowing down those increases?

Answer: Numerous technical questions have surfaced relating to unexpected machine performance, higher structural loads, array operation, control and siting issues and possible new environmental concerns (noise and TV interference). These problems can potentially effect the life and safety and certainly the performance of the numerous windfarms being built. Even though there have been over 4000 machines installed in the past 2 years involving some $500M private investment, most are in the 50-100kw size. As industry proceeds toward larger sizes, engineering and design issues are more complex and the technical risks and potential for serious problems increase. We are proposing to expand our research efforts to address the issues and problems anticipated for intermediate size machines (100-1,000 kW).

Without this increased funding, key research and the planned design and construction of new horizontal axis and vertical axis test beds, needed to replace the outdated Mod-0 and 17-meter Darrieus wind turbines, must be deferred.

QUESTIONS FROM THE MAJORITY

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| Question 13: | What are the Department's plans for the management of the horizontal axis aerodynamics and structural research program in light of NASA's decision to phase-out of wind energy research? |
| Answer: | NASA has advised the Congress and DOE that, in view of increased responsibilities in aeronautics and space research at the Lewis Research Center, continued long-term support for the wind program will be difficult. They have, however, reaffirmed their commitment to suport the Mod-2 and Mod-5 wind turbine projects and related technology activities as long as they can continue to contribute to the project objectives. We believe NASA support has been and continues to be important for the success of these projects and anticipate their involvement through 1986. Plans to transition this work to other labs involved in the wind program have not yet been finalized. This will be addressed as part of a long range wind program planning effort scheduled for this spring and summer. |

## QUESTIONS FROM THE MAJORITY

Question 14: The small wind industry is now beginning to build and install intermediate-sized machines. What are DOE's plans for research to support industry in this new development?

Answer: The Wind Energy Technology program objective is to provide a generic technology base that will enable the private sector to develop and utilize wind energy systems in all sizes. Because of industries' interest in developing 100-1000 kW intermediate machines, we are planning to focus more research in that size range. Specifically we are requesting FY 1985 funds to design and build two new test beds to replace the outdated Mod-0 and 17-meter Darrrieus experimental turbines. These new horizontal and vertical axis machines will be designed to permit concept testing which can be scaled up to intermediate speed machines.

Major technical questions exist with regard to intermediate horizontal and vertical axis systems and there exists very little experimental and operating data. Primary concerns are loads associated with air turbulence induced vibration and structural dynamics. This is coupled with uncertainties regarding fatigue life/material failure and ultra-high cycle limits. These factors combine to create many uncertainties in design requirements, weight, cost estimates, lifetime and safety. Our plans are aimed at reducing these risks.

QUESTIONS FROM THE MAJORITY

Question 15: Now that the Department has requested funds for this program, has a multi-year plan been prepared to guide the research? If not, has the Department set a timetable for preparing such a plan?

Answer: No ocean energy program multiyear plan exists at this time. A multiyear program plan is scheduled for completion by August, 1984.

## QUESTIONS FROM THE MAJORITY

Question 16: The OTA Staff report on OTEC (January, 1984) and several participants at the OTA OTEC workshop on February 9 and 10 cited a lack of focus to the Federal OTEC R&D effort. What is the Department's view of the principal short-range and long-range objectives of the OTEC program and the principal R&D activities that must be carried out to meet those objectives?

Answer: The principal long range objective of the program is to develop a technological data base and reduce the high risk technical uncertainties associated with ocean derived energy sources such as ocean thermal in order to furnish industry sufficient knowledge to commercialize the technology and achieve significant energy production capability if warranted by cost or other considerations. The short range objectives are to characterize material performance, to experimentally verify performance predictions, and to develop generic models for advanced concepts. These efforts are directed towards reduction of technical risk, achieving increased performance, reduction of life cycle cost, verification of life cycle cost projections and accurate projection of operations, maintenance and repair requirements.

The principle R&D activities that are planned to meet these objectives are cold water pipe materials-research and deployment modeling, completion of a conclusive biofouling research program on aluminum, closed cycle heat exchanger material investigations aimed at water side enhancement for aluminum and possibly thermoplastics, open cycle heat and mass transfer experiments including non-condensible gas removal and possible environmental consequences, and the analysis of effluent environmental impacts and plume modeling.

QUESTIONS FROM THE MAJORITY

Question 17: There appear to be six national laboratories or government institutions carrying out research in a program with a requested budge of less than $4 million. Does DOE have plans to re-structure its fiel activities to reflect the new fiscal realities? Please describe those plans.

Answer: DOE is planning to re-structure its field activities in ocean energy to reflect the proposed FY 1985 budget level of $3.5 million. The proposed organization of field activities, presently under review, would reduce the six national laboratories and government institutions directly funded by DOE to three by FY 1985.

## QUESTIONS FROM THE MAJORITY

Question 18: One method of technology transfer used by the British industrial energy conservation program is for the government to cost share a fraction (roughly 25 percent) of a commercially funded prototype test of a new technology and receive in exchange the right to collect and disseminate data about the system. Would the Department be favorably disposed toward such a technology transfer initiative if it were were proposed by Congress? Does the Department foresee any administrative problems in carrying out such a program if funds were appropriated by Congress?

Answer: The Administration's policy on R&D spending is to focus its support on basic and applied research that is not likely to be done by industry but which will result in a technology base for industry development, demonstration and commercialization activities. Additional government incentives for industry activities, including prototype tests, are currently provided through tax credits.

The concept of government cost sharing some part of commercially funded prototype tests in exchange for rights to develop and disseminate case study type information raises some interesting issues. In order to determine its effectiveness from a U.S. standpoint a comparative examination and analysis of the various total financial and fiscal incentives offered by the U.S. and other countries and their effectiveness would have to be considered.

## QUESTIONS FROM THE MAJORITY

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| Question 19: | What is the Department's position on solar resource assessment? Is further work at the university meteorological research stations set-up by DOE in FY 1978 still justified? Has NOAA provided adequate funding for the national solar data network? What actions could Congress take to remedy problems? |
| Answer: | The Department believes that continued solar data acquistion and resource assessment capabilities are needed by a range of industrial and DOE R&D organizations engaged in renewable energy technology. It is also used by any organization requiring careful characterization and modelling of long-term and current solar radiation data. While there has been a downturn in the university meteorological research station program and the NOAA activities involving the U.S. 38-station network to acquire and achieve general U.S. solar radiation data, the on-going DOE assessment, characterization, and modelling work being conducted for DOE by the Solar Energy Research Institute constitutes an appropriate level of solar resource effort at the present time. |

QUESTIONS FROM THE MAJORITY

QUESTION 20. Crosscutting Research. A number of research managers have suggested that it might be worthwhile to create a separate line item for crosscutting advanced applied research in solar energy, such as solar resources assessment or photochemical conversion, that is not specific to any one solar technology. What is the Department's position on the merits of such an initiative?

ANSWER: DOE is convinced that advanced research is essential to resolving crosscutting technical barriers affecting the viability of renewable energy technologies and for opening new avenues of applied research through acquiring an increased understanding of the various solar energy phenomena. A healthy competition between advanced research and more established mission or goal oriented activities has led over the past few years and in the DOE FY 1985 budget proposal to an increased emphasis on the types of investigations suggested in your question. We conclude that advanced research is fairly considered and adequately supported within the current renewable energy program structure, and that creation of a new budget category is not necessary to accomplish our mutual objectives in this area.

## QUESTIONS FROM THE MAJORITY

Question 21: SERI Facility: Does the Department believe that a permanent laboratory facility should be built for the Solar Energy Research Institute? What are the Department's plans for requesting funds for such a facility?

Answer: Past accomplishments in Solar Energy Research has created the need to reevaluate programmatic direction and emphasis at SERI. Within this evaluation process DOE is currently analyzing the future direction, resource requirements and facility needs of SERI. Once the process is complete a decision as to the need for additional facilities and their makeup will be made.

## GEOTHERMAL ENERGY

## QUESTIONS FROM THE MAJORITY

Question 1: How many design wells will be operated with the FY 1985 budget request? Will any funds be available for contingencies such as the problems with Gladys McCall in FY 1984? How much of the $3.5 million requested for FY 1985 will go to operating design wells and how much to supporting analysis and modelling activities?

Answer: The FY 1985 budget request is adequate for the planned operation of two design wells in FY 1985: the Pleasant Bayou well and the Gladys McCall well. Approximately $2.0 million will support well testing and $1.5 million will be spent on supporting research and analysis. While major maintenance costs similar to those encountered previously are not expected, contingency funds to handle emergency problems will be available.

## QUESTIONS FROM THE MAJORITY

Question 2: What is the Department's position on the desirability of acquiring the Hulin well? Are any funds provided in the FY 1985 budget request for such an acquisition? How much would it cost the government to obtain the rights to the Hulin well?

Answer: The Department now is in the process of acquiring legal rights to conduct future experimental tests with the Hulin well. The acquisition cost of these rights is expected to be about $25,000, which could be funded with FY 1984 appropriations.

## QUESTIONS FROM THE MAJORITY

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| Question 3: | What is the Department's estimate of the thermal production capacity (in megawatts) of the large fracture system created by the December 1983 fracturing experiment? What is the Department's estimate of the funds that would be required in FY 1985 to complete the circulation loop by drilling into the fracturing from the production well and carry out full power extraction experiments in the new, larger fracture? |
| Answer: | During the venting of the well after the recent fracturing experiment, energy production rates as large as 115 megawatts were observed. However, these rates are not expected to be sustainable over long periods of time. The average thermal capacity of the hot dry rock reservoir will depend on the nature of the circulation loop between the two wells and the thermal drawdown rate. Preliminary data suggests the reservoir's capacity could exceed 30 thermal megawatts over an extended period of operations. The FY 1985 projected budget of $10.6 million, consisting of the Administration's request plus contributions from Japan and West Germany, is considered adequate to support the tasks required to establish the large circulation loop. |

## QUESTIONS FROM THE MAJORITY

Question 4: State Planning Activities. What will happen to state resource planning activities initiated in FY 1984 if no funds are provided for this activity in FY 1985?

Answer: The state resource planning activities are being continued in FY 1984 with funding obligations sufficient to complete them. Costing of certain tasks will carry over into FY 1985, but funding will not be needed and none was requested.

## QUESTIONS FROM THE MAJORITY

Question 5: Technology Transfer: What activities will be carried out with the increased resources requested for this activity in FY 1985?

Answer: Technology transfer activities will consist largely of topical meetings, program reviews with industry, sponsorship of seminars with such groups as the Geothermal Resources Council (GRC), publication of definitive technical reports and handbooks, publication of technology transfer articles in the GRC bulletin, and use of Technical Information Center for dissemination of technical publications. The Interagency Geothermal Coordinating Council, and cooperative activities with other Federal agencies, especially the US Geological Survey and the Department of Defense, will be emphasized as effective avenues of technology transfer. Cooperative technology transfer efforts on a cost-sharing basis with the Electric Power Research Institute will be used to maximize technology transfer. Results of information gained from international programs (particularly those with Italy and Mexico) will be rapidly transferred to U.S. industry by preparation and dissemination of topical reports.

## QUESTIONS FROM THE MAJORITY

Question 6: Deep Well Experiment. What is the status of the solicitation for the $5.9 million deep well drilling experiment authorized in the FY 1984 geothermal appropriation?

Answer: The Department is proceeding with a competitive solicitation to develop a deep well in the Salton Sea geothermal area for scientific investigations and we expect several responses. The RFP release is planned for March 9, with contract award expected by late summer.

DON FUQUA (Fla.), Chairman

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General Counsel
DAVID S. JEFFERY
Minority Staff Director

February 15, 1984

Hon. Pat Collins
Under Secretary
Department of Energy
Washington, D.C. 20585

Dear Mr. Collins:

Attached are a number of questions regarding the Department's FY 1985 budget request for conservation, solar, and geothermal energy research and development. The answers will be most helpful to the Committee as it marks up the FY 1985 DOE Civilian Research and Development Authorization next month.

We appreciate your willingness to testify before the Subcommittee on Energy Development and Applications, and would like to have your written answers to the enclosed questions no later than March 9.

Sincerely,

DON FUQUA
Chairman

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5. Analysis and Technology Transfer. What is the rationale for creating a new energy efficient buildings center rather than working with existing building industry trade associations, and state and local government agencies to disseminate information about energy efficient buildings? Were NAHB, AIA, ASHRAE, NIBS, or any other building industry organizations involved in preparing this initiative?

6. Buildings and Community Systems Program Direction. Please explain the rationale for reducing the staffing level from 71 FTE's to 60 FTE's while increasing the budget request for program direction from $2.9 million to $3.1 million.

7. Please explain the source of the $10,077,000 in prior year balances "that are being credited against the energy conservation account." Also provide details of the $8,000,000 in savings from management initiatives.

8. Industrial Program. How does the industrial program coordinate its efforts with those of fossil energy in areas of mutual interest such as coal-fired Brayton engines, slagging coal burners and coal-water diesels? How are management decisions and funds allocated between CE and FE in these areas?

9. Industrial Program. Is $3.8 million sufficient to fund all activities required in FY 1985 in conjunction with the thin strip steel casting pilot plant initiative? Please provide a copy of the work statement associated with the RFP for this project. When will an award be made?

10. Industrial Program. Why have funds for national laboratory support been reduced from FY 1984 levels in the FY 1985 request? What support activities will be curtailed or eliminated as a result of this reduction?

11. Industrial Program. Will any separations research projects be terminated before completion as a result of budget reductions in this area? Which projects will be terminated and what are the FY 1985 funding requirements to continue them?

## FY 1985 DOE Authorization Budget Questions
## Conservation Research and Development

1. The Administration has requested capital equipment funds of $2.5 million for buildings and community systems, $4.4 million for industrial energy conservation, and $3.4 million for energy conversion and utilization technologies. For each request please specify how the funds will be allocated by sub-program and by national laboratory, and provide a list of specific items to be procured.

2. Building Systems. The Administration has requested no funds for building systems interactions and very little funding for whole building performance R&D, despite strong recommendations for funding in this area in the Carmel Valley workshop report and elsewhere. Please explain the rationale for this decision. What useful research, appropriate to the federal role, could be done in this area with additional funding?

3. Community Systems. Please describe and provide a rationale for each of the tasks listed on pp. 46 and 47 under integrated community energy systems. Were industry and local government officials involved in planning the FY 1985 request in this area? Does DOE have a multi-year plan for research and development related to community systems? If so, please provide two copies for EDA Subcommittee staff.

4. Technology and Consumer Products. Why were no funds requested for refrigeration systems and combustion heating equipment in the FY 1985 budget request? What on-going activities will be terminated as a result of this decision? If Congress were to appropriate funds in these two areas for FY 1985 what would be the highest priority activities to carry out, in the Department's view?

12. Industrial Program. Please describe the proposed national information center for industrial conservation technology and describe the rationale for its creation. What funding level is requested for the center in FY 1985?

13. Transportation. Why are no funds requested for alcohol fuels in the alternative fuels utilization sub-program area? Will any projects be terminated before completion as a result of this budget request?

14. Transportation and ECUT. DOE has requested $9 million for materials research in transportation (ceramics plus advanced materials) and $6 million for materials research in ECUT. It also has requested a large increase in materials research in basic energy sciences. How do the conservation materials program initiatives differ from each other and from those in basic energy sciences? How does the Department insure that no overlap takes place in research in this area?

15. ECUT. The Department has proposed a three-fold increase in materials sciences in FY 1985. What is the rationale for such a rapid scale-up? What would be lost if the planned program expansion were phased in over a two or three year period?

16. ECUT. Much of the work proposed for FY 1985 on long range ordered alloys and intermetallic compounds, physical chemistry of inorganic non-metalic materials and materials structure and design appears to be of a basic research nature. Why is it not being transferred to the basic energy sciences program?

17. ECUT. Please explain the rationale for the three- and four-fold increases proposed for catalysis and biocatalysis and wear testing, and tribiological coatings and innovations? What would be the impact on the programs of reducing the rate of growth?

18. ECUT. How much of the $3.4 million requested for capital equipment will be devoted to "planning and design of early phases of building a new unclassified research facilty. . .in support of the ECUT program"?

## FY 1985 DOE Authorization Budget Questions
## Solar Energy Research & Development

1. Please explain the $10,052,000 in "undistributed" funds and the $32,300,000 in savings from management initiatives in the table on p. 18 of volume 2 of the budget books. Is a deferral of $10,052,000 planned for FY 1984? What will be in it?

2. Solar Building Energy Systems. Please explain the rationale for the sizeable reductions proposed in systems simulation and analysis; daylighting and resource characterization; heat transfer; passive cooling systems research; performance monitoring and evaluation and design tools and technology transfer. Please explain how these reductions are consistent with the recommendations of the Carmel Valley workshop. What activities would be carried out in these areas if Congress appropriated sufficient funds to restore them to their FY 1984 levels?

3. Photovoltaics. Why were no funds requested for systems experiments? Who will operate the RES's and collect and analyze data from the PRD's in FY 1985? Why has flat plate collector research been cut from $7.5 million in FY 1984 to $4.5 million in FY 1985?

4. Photovoltaics. The FY 1985 budget request appears to deviate significantly from the Five Year Plan submitted to Congress last year, both in funding level ($64 million/year vs. $47.5 million) and support for collector and systems R&D. Please explain the rationale for this deviation. Can the goals of the plan be achieved with the funding levels proposed in the budget?

5. Photovoltaics. Are funds requested to continue the block purchases and module testing activities at JPL in FY 1985? If not, why not?

6. Solar Thermal. What is the status of the PON for Small Community Experiments #1 and #2?

7. Solar Thermal. What is the Department's assessment of the likelihood of the Carizo Plains or Solar 100 powerplants being built, assuming the Federal solar business tax credits are not extended by Congress? Assuming they are? If these plants are not built what will be the consequences for the central receiver industry? Are there any other actions the Federal government could take to assist industry in comercializing this technology?

8. Biofuels. The Department has proposed significantly increased funding for production-related research and decreased funding for conversion-related research in the FY 1985 request. What is the rationale for this change in emphasis? Is there sufficient funding in the biochemical conversion request to carry out all activities formerly carried out by the alcohol fuels, municipal waste and biomass programs? What activities, if any, have been discontinued in this area?

9. Biofuels. What is the rationale for the proposed reduction in funding for the biomass regional programs in the DOE FY 1985 budget request? What is the status of the Northeast and Great Lakes regional biomass programs?

10. Wind. What are the FY 1984 funds required to close out the MOD-5A program? What does the Department propose to do with unexpended funds from the FY 1984 MOD-5A budget allocation?

11. Wind. What is the Department's position on cost-sharing for the MOD-5B? Has DOE set a date by which Boeing must produce a firm cost-sharing proposal or have the MOD-5B program terminated?

12. Wind. Please explain the rationale for the large increases proposed for aerodynamic and structural research. What would be the consequence of delaying or slowing down those increases?

13. Wind. What are the Department's plans for the management of the horizontal axis aerodynamic and structural research program in light of NASA's decision to phase out of wind energy research?

14. Wind. The small wind industry is now beginning to build and install inter-

mediate-sized machines. What are DOE's plans for research to support industry in this new development?

15. OTEC. Now that the Department has requested funds for this program, has a multi-year plan been prepared to guide the research? If not, has the Department set a timetable for preparing such a plan?

16. OTEC. The OTA staff report on OTEC (January, 1984) and several participants at the OTA OTEC workshop on February 9 and 10 cited a lack of focus to the Federal OTEC R&D effort. What is the Department's view of the principal short-range and long-range objectives of the OTEC program and the principal R&D activities that must be carried out to meet those objectives?

17. OTEC. There appear to be six national laboratories or government institutions carrying out research in a program with a requested budget of less than $4 million. Does DOE have plans to re-structure its field activities to reflect the new fiscal realities? Please describe those plans.

18. Technology Transfer. One method of technology transfer used by the British industrial energy conservation program is for the government to cost share a fraction (roughly 25 percent) of a commercially funded prototype test of a new technology and receive in exchange the right to collect and disseminate data about the system. Would the Department be favorably disposed toward such a technology transfer initiative if it were proposed by Congress? Does the Department foresee any administrative problems in carrying out such a program if funds were appropriated by Congress?

19. Solar Resource Assessment. What is the Department's position on solar resource assessment? Is further work at the university meteorological research stations set up by DOE in FY 1978 still justified? Has NOAA provided adequate funding for the national solar data network? What actions could Congress take to remedy problems in this area?

20. Crosscutting Research. A number of research managers have suggested that it might be worthwhile to create a separate line item for crosscutting advanced app~~lied-re~~search in solar energy, such as solar resources assessment or pho-

tochemical conversion, that is not specific to any one solar technology. What is the Department's position on the merits of such an initiative?

21. SERI Facility. Does the Department believe that a permanent laboratory facility should be built for the Solar Energy Research Institute? What are the Department's plans for requesting funds for such a facility?

## FY 1985 DOE Authorization Budget Questions
## Geothermal Research and Development

1. Geopressured. How many design wells will be operated with the FY 1985 budget request? Will any funds be available for contingencies such as the problems with Gladys McCall in FY 1984? How much of the $3.5 million requested for FY 1985 will go to operating design wells and how much to supporting analysis and modelling activities?

2. Geopressured. What is the Department's position on the desirability of acquiring the Hulin well? Are any funds provided in the FY 1985 budget request for such an acquisition? How much would it cost the government to obtain the rights to the Hulin well?

3. Hot Dry Rock. What is the Department's estimate of the thermal production capacity (in megawatts) of the large fracture system created by the December, 1983 fracturing experiment? What is the Department's estimate of the funds that would be required in FY 1985 to complete the circulation loop by drilling into the fracture from the production well and carry out full power extraction experiments in the new, larger fracture?

4. State Planning Activities. What will happen to state resource planning activities initiated in FY 1984 if no funds are provided for this activity in FY 1985.

5. Technology Transfer. What activities will be carried out with the increased resources requested for this activity in FY 1985?

6. Deep Well Experiment. What is the status of the solicitation for the $5.9 million deep well drilling experiment authorized in the FY 1984 geothermal appropriation?

Department of Energy
Washington, D.C. 20585

March 20, 1984

Mr. Dan Steinway
Minority Counsel
Subcommittee on Energy Development
and Applications
Committee on Science and Technology
Washington, D.C. 20515

Dear Mr. Steinway:

On February 28, 1984, Under Secretary Pat Collins testified before the Science and Technology Subcommittee on Energy Development and Applications to discuss the FY 1985 authorization for conservation and renewable energy programs.

Following that hearing, Minority members of the Committee submitted written questions for responses. Enclosed are the answers to those questions.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

for Thomas N. Pretorius

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Ms. Christine Wegman

# POST-HEARING QUESTIONS

FOR

SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

ON THE

FY 1985 DEPARTMENT OF ENERGY BUDGET

DEPARTMENT OF ENERGY WITNESS
PAT COLLINS, UNDER SECRETARY
U.S. DEPARTMENT OF ENERGY

FEBRUARY 28, 1984

## QUESTIONS FROM THE MINORITY
## MANAGEMENT INITIATIVES

Question 1. In its FY 1985 budget request, the Department indicates that it plans to save $8 million funding from various new management initiatives. Would you please briefly discuss these new initiatives and identify the areas where these initiatives will take place in the conservation area.

Answer: The FY 1985 Congressional budget request reflects savings of $8.0 million in budget authority resulting from implementation of a management initiative (Financial Systems Reforms). This initiative, described below, is designed to improve the efficiency and effectiveness of Departmental management systems and to place the Department's financial systems on a more business-like basis. Implementation of the initiatives will not only improve current Departmental operations, but will hold out the possibility of additional savings in future years.

The management initiatives for Energy Conservation programs reflect the first implementation efforts for recommendations contained in various studies of Departmental operations, including the President's Private Sector Survey on Cost Control (the Grace Commission), and the Federal Laboratory Panel of the White House Science Council (the Packard Report), as well as the Administration's program of improved management systems known as Reform 88.

The $8.0 million in estimated savings in Energy Conservation programs is attributed to Financial Systems Reforms. This initiative will save $4.0 million in FY 1984 and an additional $4.0 million in FY 1985 through improved management of the deobligation of multi-year funds. Deobligations may occur due to contract close-out, contractor defaults, or other instances of contractual dollar reductions, such as cost disallowances based on audit results. Under this initiative, deobligations will be reported and evaluated to determine whether or not the funding should be retained in the program area where it was originally appropriated. If it is determined that the funds are not needed in that program area, they will be deferred, if necessary (i.e., FY 1984 and previous years funding), and used to offset budget authority in FY 1985.

## QUESTIONS FROM THE MINORITY

Question 2: A previous appropriation bill set in law "floors", for staffing for the Department's conservation programs. Do you believe these "floors" are still necessary?

With an increased funding request for FY 1985, do you believe it will be necessary to add new staff for the upcoming fiscal year?

Are there plans to add more staff?

In particular areas, such as the community systems program where there has been in the past only one Headquarters staff person?

Answer: The staffing levels proposed for the FY 1985 conservation programs are below the legislated "floors" as we believe the requested levels are sufficient to carry out the proposed programs. Our Federal and Community Programs Division currently has 9 full-time permanent employees on board.

## QUESTIONS FROM THE MINORITY

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| Question 3: | As you are aware, the Department has in the past had a full-time Assistant Secretary for Conservation and Renewable Energy. Are there any plans that you are aware of at the present time to appoint a permanent Assistant Secretary, or will the Under Secretary continue to fulfill these responsibilities? |
| Answer: | Although I presently cannot give a specific date for completion of the selection process, it is my intention to make a final recommendation to the President within the relatively near future. |

## QUESTIONS FROM THE MINORITY

Question 4: The Congress has continued to reexamine the need for an extension of the energy tax credits. Does the Department have a position with respect to the need to continue any tax incentives for conservation investments?

Answer: The Secretary of Energy has had discussions with Treasury Secretary Regan and many others in the Administration on energy tax credits and is continuing to discuss all types of incentives in the conservation and renewable areas. The Department of Energy believes that energy tax credits help provide a mixed and balanced energy supply for the Nation by supporting the development of new industries that might not otherwise be competitive. Also, R&D spending helps facilitate the development of new technologies associated with a variety of fuels as well as energy conservation and renewable resources.

However, at the same time, there are other factors which must be considered such as concerns over the most efficient utilization of resources in the private sector and the impacts on the federal budget deficit.

## QUESTIONS FROM THE MINORITY

## DISTRICT HEATING AND URBAN WASTE PROGRAMS

Question 5: In the buildings and community systems area, the Committee has long been interested over the years in several key programs, including the district heating and cooling initiatives and the Department's urban waste program. What is the status of these programs, and does the FY 1985 budget include funding for these activities. If so, please discuss.

Answer: District Heating and Cooling. During recent years, the District Heating and Cooling program has been limited to a few key projects: the Georgetown University Integrated Community Energy System (ICES), the Scranton Mine-Water Heat Pump project, and the DOE/HUD-sponsored studies of the feasibility of district heating in 28 cities.

Although it is shut down at the moment to investigate a boiler tube erosion problem, the Georgetown ICES has been operating to produce heat and the turbine to generate electricity has been ordered. Our FY 1984 appropriation contained $800,000 for this project which the language of the Resolution Committee report indicates is not expected to receive further Federal funding.

The Scranton Mine-Water Heat Pump project is continuing. Recent analyses have revealed that the demonstration projects as initially conceived would not be cost-effective. Therefore, a new research effort has been initiated to evaluate 15 alternative systems concepts. If any are found to be economically feasible, one or more will be selected for further development. Such a system is expected to be applicable in any area where ground water at a temperature of about 55°F is available.

DOE/HUD-Sponsored District Heating Feasibility Studies. The DOE-HUD Phase I studies of the feasibility of district heating have been completed and have produced an interesting result. Of the 28 cities involved, 12 have proceeded with further development, 6 of them without additional Federal funding. Nine of the twelve are conducting marketing and financial planning studies and 3 have systems under construction. We expect that ultimately 10 of those 12 cities will build district heating systems.

Systems Under Construction

Baltimore, MD*
Provo, UT*
Lawrence, MA*

Marketing and Financial Studies

New York, NY*
Lewiston, ME*
Springfield, MA*
Devils Lake, ND
Atlanta, GA
Richmond, IN
Holland, MI
Campbellville, KY
Columbus, OH

*Received Phase II funding from HUD

Because of the success of the DOE-HUD 28 cities feasibility studies, DOE plans to initiate some additional Phase I feasibility studies in FY 1984. We are exploring with HUD the possibility of continued joint DOE/HUD sponsorship.

The FY 1985 funding request for Community Systems is $2.0 million. All of these funds are for research and development related to district heating and cooling systems. (There will be sufficient carryover funds to support the Scranton project during FY 1985.)

Urban Waste. The requested program funding for urban waste, is $3 million which is included under the Biomass line item. These funds will be used to continue the development of data bases from which industry can demonstrate and implement urban waste systems producing liquid and gaseous fuels. In addition, research will provide fundamental information in cooperation with the combustion landfill gas and mechanical processing industries to increase their efficiency and reduce environmental concerns.

Thermochemical conversion research is continuing to acquire fundamental knowledge of the basic mechanisms, kinetics, and thermodynamics involved in the pyrolysis process. The intent is to provide a data base that can be used in developing reactors to produce liquid and gaseous fuels. Specific projects to be continued include determination of products on the molecular scale plus the effect of temperature, time, etc. Since one of the most difficult problems related to thermochemical conversion of municipal solid waste (MSW) is environmental emissions control, research is ongoing to identify the mechanisms of pollutant formation and destruction so that industry can design and develop more environmentally acceptable processes. This effort has been identified by industry as their number one priority.

Both the thermochemical and biochemical conversion processes require the preparation of the feedstock. The problems are due to the heterogeneous nature of MSW, the use of processing equipment that has been adopted from other industries and the fact that required refuse derived fuel (RDF) feedstock specifications are not yet known. To help resolve these problems, basic unit operations of RDF processing equipment are being studied to provide industry with a basis for advanced system design and optimization. Other research seeks to develop an inexpensive chemical binder for diversified RDF to improve its transportability and long-term storability. In addition, new equipment concepts are being explored to determine if RDF processing systems can be economically developed for the smaller community.

In biochemical research, prior year efforts to establish a technical data base are continuing. This research includes studies of the basic physiology and metabolic pathways of methane-producing organisms, microbial conversion of municipal solid waste to organic acids for conversion to liquid fuels, and the improvement of anaerobic digestion efficiency. The results of these research efforts will be tested at the Refuse Conversion to Methane (RefCom) proof-of-concept facility located in Pompano Beach, Florida. The RefCom facility has confirmed earlier laboratory results and developed an effective feed system. During FY 1985, efforts will concentrate on developing a data base for a pilot scale activity that is expected to be funded by others.

Currently no research is being conducted in the wastewater treatment energy conservation area. However, prior work has demonstrated the need for a data base to improve the operation of anaerobic digestors for methane production. Funds have been requested to continue work in this area in FY 1985.

## QUESTIONS FROM THE MINORITY

## CAPITAL EQUIPMENT FUNDING

Question 6: The Department has requested this year a significant amount of new funding for capital equipment ($2,500,000) for the building and community systems program. How would this funding be spent? Do you believe that this request is sufficient to satisfy all the needs to replace, for example, outmoded test equipment at the DOE national laboratories?

Answer: Details of how the Building and Community Systems program would use the requested funding for capital equipment are presented on the attachment to this question. We believe that the amount requested is sufficient to satisfy the high priority needs to replace outmoded test equipment at the national laboratories, to support enhancement of our roof testing capability, and to initiate development of a building model simulation testing capability.

The following table covers the Building and Community Systems subprograms capital equipment requirements for FY 1985.

| BUILDING SYSTEMS SUBPROGRAM | (Dollars in thousands) |
|---|---|
| Lawrence Berkeley Laboratory | |
| Windows and Daylighting | |
| Expand capability of MoWiTT module to permit simultaneous dual-orientation testing | 200 |
| Building Energy Use Simulation | |
| Two 176 megabyte disk drives @$18K | 36 |
| Two tape drives @$22K | 44 |
| Energy Performance of Buildings | |
| Mobile infiltration and ventilation efficiency measurement system (MIVE) | 150 |
| Multi-chamber AC pressurization apparatus | 50 |
| Passive wall thermal performance measurement system | 75 |
| Building Energy Data Acquisition | |
| Field monitor data acquisition system for BECA | 50 |
| Two Microprocessor data acquisition systems @$5K | 10 |
| Ventilation and Indoor Air Quality | |
| Gamma spectrographic source monitor | 10 |
| Two continuous radon monitors @$5K | 10 |
| Field computer system | 10 |
| Tracer gas field monitoring system | 15 |
| Ventilation monitoring and data acquisition system | 25 |
| Sample concentrator | 9 |
| Portable gas chromatograph with photo-ionization detector | 9 |
| Data logging system | 5 |

| | |
|---|---|
| Photo-ionization detector, electrometer, and power supply | 4 |
| Magnetic cassette recorder | 5 |
| National Bureau of Standards | |
| Upgrading of guarded hot plate for testing aerogels in vacuum | 20 |
| Building monitoring equipment | 35 |
| Completion of upgrading of calibrated hot box | 20 |
| Oak Ridge National Laboratory | |
| Test apparatus for evaluating roof system thermal and moisture transport characteristics under controlled conditions | 720 |
| Environmental test chamber for flat insulation testing | 100 |
| Massachusetts Institute of Technology | |
| Instrumentation for building model test apparatus | 50 |
| Princeton University | |
| Humidity measurement equipment | 18 |
| Building energy use monitoring and metering instrumentation | 12 |
| Computational system for building energy use monitoring | 13 |
| Infrared scanner | 29 |
| Princeton University | |
| Recorder for infrared scanner | 2 |
| Dedicated computer for infrared scanner system | 14 |
| Solar Energy Research Institute | |
| Glass processing vacuum oven and edge sealing apparatus | 50 |
| Subtotal | $1800 |

## FEDERAL ENERGY MANAGEMENT PROGRAM (FEMP)

| | |
|---|---|
| Equipment and instrumentation to be used by Federal agenices in establishing baselines for planning and monitoring shared-savings projects | 100 |
| Subtotal | $ 100 |

## TECHNOLOGY AND CONSUMER PRODUCTS SUBPROGRAM

| | |
|---|---|
| Lawrence Berekeley Laboratory | |
| Plasma Diagnostics Laboratory | 100 |
| Oak Ridge National Laboratory | |
| Absorption Heat and Mass Transfer Laboratory | 260 |
| Heat Pump Breadboard Test Facility | 35 |
| Field Test Data Acquisition Equipment | 205 |
| Subtotal | $ 600 |
| TOTAL BUILDINGS AND COMMUNITY SYSTEMS | $2,500 |

## QUESTIONS FROM THE MINORITY

### R&D PROGRAM MANAGEMENT

Question 7: Several reports over the past years (OTA and GAO studies) have criticized the lack of forms and direction and inadequate evaluation of overall programmatic goals. Do you believe these criticisms have been addressed?

While the Department has requested this year a significant increase in funding for analysis and technology transfer for several new initiatives (i.e., a fellowship program and an Energy Efficient Building Center), will any of this funding be used to support overall program management activities?

Answer: As Under Secretary, I have special oversight responsibility for all energy conservation programs. Things have changed considerably since the time of the critical reports.

We are continually seeking advice on how to improve our programs, inviting critics to review our efforts and make constructive suggestions, opening our decision processes to outside scrutiny, and in general, going forward with renewed commitment to conservation goals.

While none of the funds designated specifically for "analysis and technology transfer" will be used for "overall" program management, we do plan to evaluate our activities and improve our program planning and management process. We have, for example, a comprehensive "Multi-Year R&D Program Plan." This is a "first" for Conservation, and we are in the process now of doing a better one for next year. Improved planning will lead to better tracking of program objectives, and better overall management.

## QUESTIONS FROM THE MINORITY

### NEED FOR CONSERVATION R&D

Question 8 : As we are all aware, the world price of oil has now dropped to a $29 per barrel level and there are some indications that it may drop even further. Given this present oil price picture, do you believe there is a need for a further governmental role in conservation R&D?

Answer: While part of the strategy adopted by the Administration for achieving our national energy policy goal of fostering an adequate supply of energy at reasonable costs is to minimize Federal control and involvement in energy markets, an equally important aspect of the strategy is to promote a balanced and mixed energy resource system. The Administration views conservation as a significantly important energy resource. Since conservation is, and will remain, an important component of the available energy resource mix, Federal research is likely to remain a useful precursor to commercialization of technologies needed to foster conservation and improved energy efficiency over the long term.

Once basic and applied research and development have been accomplished, the pace at which new or alternative technologies are commercialized and marketed will be determined, not by the Federal government, but by entrepeneurs and consumers. The Federal government will continue to emphasize the importance of technology transfer efforts to ensure that the results of publicly supported R&D are available widely and promptly to the marketplace.

## QUESTIONS FROM THE MINORITY

## WHOLE BUILDINGS RESEARCH

Question 9: During a recent workshop on building energy conservation, several industry representatives pointed out it was essential for the DOE to continue to support systems-related activities, such as whole buildings research. These representatives stressed that without this support, it would be very difficult to bring new innovations developed under the DOE program to the marketplace, since industry is generally reluctant to invest in new technologies unless these technologies have already been tested in a real-world situation such as a systems test.

Would you please comment?

Answer: The Department believes that systems-related activities, such as whole buildings research, are important and we are supporting these activities in a number of ways, even though the specific item identified as "Building Systems Interactions" has been zeroed out in the FY 85 budget.

The planned activities that support this area include a significant expansion of the Performance Calculations effort which provides the analytical computer tool used by researchers and architects to understand building systems interactions. In addition, the Guidelines and Standards work will be continued with plans for the issuance of interim Guidelines for the private sector and interim Guidelines for new Federal buildings and the initiation of a demonstration of these Guidelines and Standards. The expanded technology transfer activity will also provide architects and engineers with the results of DOE research so that this information is more accessible for use in the design of new buildings.

We believe the DOE funds should be used in these ways to give building designers the tools they need to design innovative energy-efficient structures. With these tools, we believe that architects and engineers can and should take the lead in using these new R&D findings in the design of new buildings.

## QUESTIONS FROM THE MINORITY

## COMMITTEE SPONSORED WORKSHOPS

Question 10: As you are aware, the Committee has sponsored several workshops relating to a national R&D program to develop more efficient technologies for building energy conservation activities. Generally, do you believe that you have responded to the recommendations made during these workshops in such areas as component development, systems applications research and technology transfer needs.

Answer: In general, I believe the Department has done a good job of responding to the statements of research needs that have come out of the workshops sponsored by the Committee, numerous private building industry associations, and DOE. The Committee and its staff should be congratulated for the leadership they have shown in convening these workshops.

The Committee took the lead in the sponsorship of the initial workshop in Carmel, California. As you know, the response of the Department to the Carmel report was one of the major subjects at the Building Energy Research Workshop II held in February 1984, in Cockeysville, Md. The review showed that the Department has active R&D programs in virtually all of the areas identified at Carmel. The workshop report was a major factor in the Department's decision to seek a major expansion of our technology transfer activities, as is reflected in the FY 85 budget. The report also has led to increased cooperation between the building conservation and solar programs. The Carmel statement was considered by DOE in the multiyear plan developed by the building research office.

There occasionally has been a time lag between the workshop statements of research needs and the decision schedule for DOE which has meant that not all of the comments were available to us as we prepared the FY 85 budget. For example, the Building Equipment Workshop last fall at Airlie House was held after the FY 85 budget had been prepared and, of course, so was the most recent meeting. We are currently reviewing the conclusions and recommendations of these recent workshops and plan to reflect them as appropriate in our future program and budget.

The workshops have been a very useful vehicle for exchanging views and for prioritizing and coordinating the R&D activities of the public and private sector in the buildings area. We at DOE look forward to continuing and improving this collaborative activity.

## QUESTIONS FROM THE MINORITY

### INDOOR AIR QUALITY

Question 11: The Committee has been extremely interested in your indoor air quality program. Of the funding requested for building systems, how much will be specifically allocated for this activity in FY 1985?

Answer: Of the $12.2 million requested for the Building Systems subprogram in FY 1985, $1.4 million is for indoor air quality research. These funds will be used to expand our limited data base on radon sources to additional regions of the U.S. and to continue our radon control studies; to extend our work on ventilation measurements in large buildings and to develop techniques for improving ventilation efficiency; to conduct a field validation of infiltration measurement techniques; and to investigate the effects of combustion appliances on residential indoor air quality.

An Interagency Coordinating Committee on Indoor Air Quality has been established. EPA, DOE, and several other agencies are members. This group has allocated areas of primary responsibility to the various agencies and coordinates the agencies' ongoing research in indoor air quality.

## QUESTIONS FROM THE MINORITY

## CAPITAL EQUIPMENT AND ENERGY SAVINGS

Question 12. In the industrial program, the Department has requested a significant increase in funding over its FY 1984 request.

(a) Would you please discuss some of the reasons for this increase, especially in the capital equipment area?

(b) Overall, how much energy savings has this program generated, and how effective has the program been in developing new technologies that are now being used commercially?

Answer: (a) The FY 1985 budget request, in concert with thee National Energy Policy Plan, October 1983, emphasizes the importance of energy conservation and, accordingly, increases the request to a level that in recent years has been approved by Congress as an appropriate level.

As a new initiative, new research equipment needs for national laboratories linked to specific projects of the industrial program have been identified. These constitute the increase in capital equipment and are intended to enhance the research efforts of the national laboratories.

(b) Based on a survey and analysis conducted by the Pacific Northwest laboratory (PNL), technologies supported by the Industrial Energy Conservation Program have resulted in energy savings of approximately 22.7 trillion Btu's per year and have, since inception, saved approximately 50.5 trillion Btu's. The current savings rate is from 23 technologies from the nearly 200 supported.

The remaining technologies are in various phases of development at this time. In view of this it is felt that the program is and has been very effective supporting the developmental new technologies that are readily accepted in the market place once successfully tested. However, it is likely that some portion of these savings would have occurred in any event due to normal market forces.

## QUESTIONS FROM THE MINORITY

## ENERGY ANALYSIS AND DIAGNOSTIC CENTERS

Question 13. The Department has recommended an expanded energy analysis and diagnostic center program for FY 1985. This program shows great promise for providing valuable energy management assistance to small and medium-size manufacturers and businesses.

While this program supports a useful activity, has any thought been given to imposing some sort of user-fee or cost-sharing requirement similar to that requirement imposed by law for the Energy Extension Service?

Answer: The number of Energy Analysis and Diagnostic Centers (EADC) has just been expanded from 5 to 10.

Consideration has been given to requiring a user-fee or cost-sharing. Follow-up surveys of manufacturers receiving audits indicates that very few would have been willing to pay for the service up front, despite the obvious cost savings which resulted. Discussions are being planned with representatives of selected utilities, to explore the possibility of using EADC results in "marketing" of energy conservation to their industrial customers. In addition, the American Consulting Engineers Council is developing a publication, which will be based on EADC results and support comprehensive energy conservation programs, for use by consulting engineers who are working on designs and equipment for industrial plants.

## QUESTIONS FROM THE MINORITY

## INDUSTRIAL TAX INCENTIVES

Question 14. There are now signficant tax incentives on the books to stimulate and encourage industrial investment. These include the accelerated cost recovery systems (ACRS) deductions and the R&D tax credits.

Has there been any work done in DOE to analyze the effect of these incentives on industrial conservation investments, and if so, what have been the results?

Have the results, if any, been reflected in the final budget recommendations?

Answer: DOE has not analyzed the effects of ACRS deductions and R&D tax credits on industrial conservation investments.

QUESTIONS FROM THE MINORITY

Question 15: (a) The Department has not recommended any funds for the Energy Extension Program for fiscal year 1985. Why not?

(b) What has been your evaluation of the effectiveness of this program to date?

(c) Of funds which were recommended, do you believe it would be appropriate to support the EES through the Petroleum Overcharge Restitution Fund?

(d) Has the Department prepared an opinion on the legality of this proposed fund, and if so, what are the conclusions?

Answer: (a) The FY 1985 budget does not contain funding for the EES because we believe it is a State responsibility to fund and operate such a service.

(b) It has been difficult to gauge accurately the effectiveness of this program. The Department considers that Federal funds for energy conservation can be used most effectively in the grant program which directly conserve energy through the installation of energy conservation equipment and supplies, thus enabling those recipients to improve their energy efficiency.

(c) No, because the Department prefers to devote funds transferred to the States to programs which directly conserve energy through the installation of energy conservation equipment and supplies, thus enabling those recipients to improve their energy efficiency.

(d) We have not prepared an opinion on the legality of the proposed fund, but have referred the proposal to the Department of Justice which had no adverse comments in that regard.

QUESTIONS FROM THE MINORITY

**QUESTION 16.** The Inventors program is recommended for a significant Increase of $2 million over the 1984 levels. What is the reason for the Increase?

Is there a current backlog of NBS-recommended projects?

Have the Federal patent law requirements hindered the effectiveness of this program?

ANSWER: The FY 1983 funds were specifically earmarked for the evaluation of inventions by NBS and did not provide funding for DOE to issue grants to inventor to support development. FY 1984 funding provided sufficient funding to support some of the recommended inventions. The proposed funding for 1985 should allow funding support for most of the recommended inventions.

The current backlog of NBS recommended invention is 50. It is anticipated that another 20 will be recommended by the end of the fiscal year. It is anticipated that at least 30 grants will be issued leaving a backlog of 40 by the end of the year. With the proposed increase in funding the backlog should be reduced to approximately 20 at the end of FY 85.

The Federal Patent law has not hindered the effectiveness of the ERIP. There is no requirement that an invention be patented or even patentable in order for the invention to be evaluated. The program does not get involved in the patent process. Application for and granting of patents must be worked out between the inventor and the U.S. Patent Office. The program does provide for waiving the government's right to title in inventions supported by DOE when the invention is submitted by an individual inventor or small company.

## QUESTIONS FROM THE MINORITY
## MATERIALS INITIATIVE COORDINATION

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| Question 17: | The Energy Conversion and Utilization Program, commonly referred to as the ECUT program, has also received a substantial increase for FY 1985, especially in such areas as materials sciences.<br>How is the materials initiative coordinated with other new materials initiatives recommended by DOE, such as the High Temperature Materials Laboratory and the Center for Advanced Materials? |
| Answer: | The Materials Sciences research in ECUT is coordinated with all the materials research and materials development activities in the Department of Energy (DOE) through a formal mechanism called the Energy Materials Coordinating Committee (EMaCC) chartered by the Office of Energy Research. EMaCC consists of representatives of every DOE program (including OER, ECUT and OVERD) having materials research components and meets monthly to review each program. For FY 1983-84, the EMaCC Chairman is the ECUT Materials Science Program Manager.<br>With regard to the High Temperature Materials Laboratory and the Center for Advanced Materials, selected projects of the ECUT Materials Science's Program are planned to be conducted in each of these unique labs when they become available. |

## QUESTIONS FROM THE MINORITY

## EIA DATA ON CONSERVATION

Question 18: As you are aware, the EIA currently has a limited program to gather information from the conservation and renewable energy industry.

Now that funding is being substantially added in these areas, what are the Department's plans to monitor through the EIA the effects of additional program support?

Answer: We agree with your concern and are working with EIA to define our basic information needs. We want to know how energy conservation and renewable energy technologies are doing in the marketplace and what effects our efforts have had. Besides EIA, we are also considering information that might be gathered by the Bureau of the Census, and by in-house and national laboratory program evaluations. We agree that programs are better managed with better information and feedback. We intend to incorporate this information into our multi-year planning process.

## QUESTIONS FROM THE MINORITY

## GOLD BOOKS

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|---|---|
| Question 19: | In prior years, the Department has sent gold books to the Committee that were extremely helpful in determining whether project milestones and goals were being met.<br>Does the Department have any plans to prepare these books again?<br>If not, why not? |
| Answer: | The Department has reinstituted the preparation of Annual Operating Plans and Multi-Year Plans which, except for the color of the cover, perform the same function as the "Gold Books." The AOP's for FY 1984 are available and will be provided to the Committee. The AOP's contain project milestones and goals and can be used to determine whether these objectives are met. The Conservation Multi-Year Plan, which discusses program plans for 1985-89, is still in draft form, but a copy of the current draft will be sent to you.<br>We see the reinstitution of these annual and multiyear plans and their review and revision each year as an essential part of good management planning for a continuing and improving conservation program. |

## QUESTIONS FROM THE MINORITY

## TECHNOLOGY TRANSFER

Question 20: While the Department has been involved in many exciting projects, the Committee has heard frequent criticism, especially in the conservation area, of the need to stimulate and encourage technology transfer.

What is being done to address this criticism?

Answer: During the past few months, the Department has taken several steps to expand and improve our technology transfer activities. Some of these new initiatives are being implemented in FY 1984; others will be implemented with the funds requested for FY 1985.

During FY 1984, the Department has initiated a "Technology Transfer '80s" program with three main work efforts. The first is a cooperative effort with State energy officials to identify successful energy efficiency innovations within their States, to provide State and national awards to recognize the most outstanding of these, and to encourage transfer of the accomplishments to others who can apply the technology.

The second effort will result in a new procedure within the Department's Office of Conservation and Renewable Energy to encourage staff to suggest innovative ways to promote the awareness, understanding, and use of techniques and technologies shown to have significant energy-saving benefits. The Department's staff will submit proposals to a review board of senior managers who will select those proposals which appear most promising and recommend special funding to implement them.

The third element of Technology Transfer '80s" involves the development of a technology transfer program plan that identifies the most effective and appropriate Federal roles to support the States and others in encouraging the transfer of available energy-efficient techniques and technologies. The plan will identify the sorts of activities the Department has underway or might initiate which would best fill critical gaps in the delivery of technologies to users.

In addition to conventional technology transfer activities such as conferences, workshops, symposia, and publications, our FY 1985 budget for Conservation includes requests for funds to establish clearinghouses for industrial and buildings energy conservation information. We are requesting $1.5 million for an Industrial Information Clearinghouse and $2.0 million for an Energy Efficient Buildings Center. These centralized sources of information for the building and manufacturing industries will collect and disseminate energy conservation information generated by government, private sector, and international sources.

We are requesting $4.9 million for fellowship programs. These programs will enable researchers from industry, academia, and State and local agencies to participate in energy conservation research and development at our national laboratories. This will improve the dissemination of information, strengthen our technology base, and support the education of engineers and scientists in energy efficiency technologies.

In addition to these new efforts involving technology transfer to the private sector, we are expanding our efforts to transfer energy conservation technologies to other Federal agencies. We have requested funds in FY 1985 to more than triple that portion of the Federal Energy Management Program that provides technical guidance and assistance to other agencies. These activities are funded at $0.5 million in FY 1984; $1.8 million is requested for FY 1985.

## QUESTIONS FROM THE MINORITY

## ENERGY EFFICIENT BUILDINGS CENTER

Question 21: The Department is recommending the establishment of an Energy Efficient Buildings Center as a new initiative.

What are the reasons for this new proposal?

Could the functions to be performed by this new center be performed by other existing mechanisms?

Answer: The Energy Efficient Buildings Center is not proposed as an alternative to working with the existing industry trade associations and State and local government agencies. It is primarily designed to enhance the procedure for getting information to these groups and to get it to other relevant groups not now served.

This initiative was developed as a result of trying to determine how information from the Federal R&D programs and information obtained from the private sector, universities, industry research organizations, State governments, and foreign governments (by means of the the International Energy Agency) could be more effectively and efficiently assembled, evaluated, and distributed to relevant target groups. NAHB, AIA, ASHRAE, NIBS, and other building industry organizations have been involved in discussions of how to improve this technology transfer activity. Information from these organizations about their information needs as expressed in special conferences and workshops has been considered.

The mechanism for implementing the planned center will be determined through a competitive selection process that will encourage widespread participation by qualified organizations.

## QUESTIONS FROM THE MINORITY

## MANAGEMENT INITIATIVES

Question 1: The Department has recommended a total of $32.3 million in savings from management initiatives in the FY 1985 budget request. Of this amount, how much will be obtained through management initiatives in the DOE renewable energy programs?

Answer: The FY 1985 Congressional budget request for Renewable Energy programs reflects savings of $9.5 million in budget authority resulting from implementation of various management initiatives. These initiatives, which are described below, are designed to improve the efficiency and effectiveness of Departmental management systems and to place the Departments financial systems on a more business-like basis. Implementation of these initiatives will not only improve current Departmental operations, but will hold out the possibility of additional savings in future years.

These management initiatives for Renewable Energy programs reflects the first implementation efforts of the Department with regard to recommendations contained in various studies of Departmental operations, including the President's Private Sector Survey on Cost Control (the Grace Commission), and the Federal Laboratory Panel of the White House Science Council (the Packard Report), as well as the Administration's program of improved management systems known as Reform 88.

The $9.5 million in estimated savings in Renewable Energy programs includes $8.0 million which is attributed to Financial Systems Reforms. This initiative will save $4.0 million in FY 1984 and an additional $4.0 million in FY 1985 through improved management of the deobligation of multi-year funds. Deobligations may occur due to contract close-out, contractor defaults, or other instances of contractual dollar reductions, such as cost disallowances based on audit results. Under this initiative, deobligations will be reported and evaluated to determine whether the funding should be retained in the program area where it was originally appropriated. If it is determined that the funds are not needed in that program area, they will be deferred, if necessary (i.e., FY 1984 and previous years funding), and used to offset budget authority in FY 1985.

The remaining $1.5 million in estimated savings results from the Procurement Reform management initiative. This effort is projected to save $0.5 million in FY 1984 and an additional $1.0 million in FY 1985 through actions designed to improve the utilization and administration of the procurement system. Specifically, increased use of contract audit support by the Department's Inspector General during contract administration is expected to expand audit coverage and increase recoveries.

The $9.5 million in projected savings from Financial Systems Reforms and Procurement Reform for Renewable Energy programs will be used to offset the FY 1985 request. Savings from other management initiatives have already been calculated into the request. For example, the budget request assumes additional savings of $1.15 million for Administrative Process/Field Structure ($1.0 million) and Procurement Reform ($0.15 million).

The $1.0 million reflects savings resulting from improved management of government owned, contractor operated (GOCO) facilities. This initiative involves improved utilization of private sector business practices by GOCO contractors through reduced procedural controls and heightened reliance on policy issuances and performance evaluation by the DOE Operations Offices.

The $0.15 million in Procurement Reform Savings results from expanded use of private sector contractors for accomplishment of commercial and industrial activities under OMB Circular A-76.

QUESTIONS FROM THE MINORITY

Question 2: What is the Department's positions with respect to and extension of the current energy tax incentives for renewable energy?

Answer: The Secretary of Energy has had discussions with Treasury Secretary Regan and many others in the Administration on energy tax credits, and is continuing to discuss all types of incentives in the conservation and renewable energy areas. The Department of Energy believes that energy tax credits help provide a mixed and balanced energy supply for the Nation by supporting the development of new industries that might not otherwise be competitive. Also, research and development expenditures help to facilitate the development of new technologies associated with a variety of fuels as well as energy conservation and renewable resources.

However, at the same time, there are other factors which must be considered such as concerns over the most efficient utilization of resources in the private sector and the impacts on the Federal budget deficit.

## QUESTIONS FROM THE MINORITY

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| Question 3: | The Department, in the past, has supported various intermediate-scale photovoltaic projects and other systems-related research activities. What is the status of such projects such as the PRDA's, the Georgetown Project, the residential experimental engineering stations, and the SMUD project?<br>Has any funding been requested for these activities for FY 1985?<br>If not, why not? |
| Answer: | Systems-related research totaling $5,000,000 in FY 1985 has been requested for Photovoltaics. The principal areas covered are (1) accelerated life testing, (2) failure analysis, (3) module lifetime research, and (4) technology transfer of testing results.<br>The specific projects named do not require FY 1985 funds. The Georgetown Project is fully funded with prior year dollars. As specified in the original contracts, ownership of the PRDA installations is being transferred to their host organizations in return for (1) continued operation at no cost to the Government, and (2) the collection and reporting of performance data to DOE for subsequent dissemination. The residential experiment stations have adequate funding for 12-24 months of continued operation, after which local sponsorship may permit sustained operation for an indefinite period. Phases I and II of the SMUD project are fully funded under a cost-shared agreement. The engineering design costs for Phase III are also funded and should permit SMUD to proceed on its own with possible additional PV system installations. |

## QUESTIONS FROM THE MINORITY

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| Question 4: | Do you believe it is necessary to support a solar resource assessment initiative?<br>If so, why? |
| Answer: | Continued assessment and updating of the solar resource is important. Since the beginning of the solar programs, DOE and its predecessor organizations have supported solar resource assessment activities. Currently, leadership and principal funding for this work is provided by the Photovoltaics program, with participation and input by the other solar programs as appropriate. The work would continue under the proposed FY 1985 budget; an expansion of the proposed activities would not provide useful returns for additional investment. |

## QUESTIONS FROM THE MINORITY

QUESTION 5: Over the years the Committee has spent a great deal of time investigating the need for permanent SERI facilities.

What is your position on this question?

Of the funding requested for FY 1985, how much do you plan to allocate to SERI and in what areas?

How much funding do you plan to earmark overall to the other DOE national laboratories involved in renewable energy, and how does this compare to FY 1984 levels?

ANSWER. Renewable Energy Program Management has undertaken a review of appropriate SERI responsibilities. Within this evaluation process DOE is currently analyzing the future direction, resource requirements and facility needs of SERI. Once the process is complete a decision as to the need for additional facilities and their specific makeup will be made.

Of the total Solar FY 1985 Presidential Budget Request, appropriately 30 percent is being proposed for allocation to SERI. The distribution of funding among the various solar R&D programs at SERI is depicted in Attachment I.

For FY 1984, an estimated $69 million in Renewable Energy funding will be distributed among DOE national laboratories exclusive of SERI. The FY 1985 budget request allocates a projected total of $78 million to those laboratories.

ATTACHMENT I

(Budget Authority in $1000s)

| SOLAR ENERGY TECHNOLOGIES | REQUESTED FY 1985 |
|---|---|
| Solar Buildings................ | $ 3,100 |
| Photovoltaics.................. | 22,000 |
| Solar Thermal.................. | 7,183 |
| Biofuels....................... | 9,500 |
| Wind........................... | 3,050 |
| Ocean.......................... | 1,400 |
| Solar Technology Transfer...... | 2,900 |
| TOTAL FY 1985 SERI-SOLAR FUNDING | $49,133 |

## QUESTIONS FROM THE MINORITY

QUESTION 6: The Department has recommended a dramatic increase in funding for FY 1985 in renewable energy compared to its FY 1984 request.

What are some of the reasons behind this request?

Does the Department believe a multi-year authorization would be helpful in more effectively managing the DOE's renewable energy programs?

ANSWER: The FY 1985 budget request for renewable energy represents a professional judgement on our part as to the level of funding required to sustain the scientific and technical momentum established to date by industry and the federal research community. Further, funding of these technologies supports the energy policy objective, as articulated within the Fourth National Energy Policy Plan, of conducting research and development of a number of potentially promising energy supply alternatives to a point where informed private sector decisions can be made regarding the viability of these technologies.

Over the past several months the Program Office has been reviewing, with senior management, renewable energy priorities in light of considerations such as the degree of remaining scientific and technical risk of specific activities, the overall stage of technology maturity, the degree of industrial development, and the nature and magnitude of potential payoffs should these technologies be deployed by industry. The results of this assessment are currently under review by DOE senior management and are intended to serve as a generalized road map for further development of

ANSWER 6. renewable energy. While not specifically a program budgeting exercise, the insights gained during the process have influenced our FY 1985 budget recommendations and will likely have some bearing on planning for FY 1986 and beyond. For instance, the results of this review are intended for use by DOE managers in the preparation of Multi-Year Program Plans for each technology.

Several conditions must exist to effectively manage longer term research and development programs. Foremost among these conditions is the establishment of a planning environment which fosters programmatic continuity and general stability. As previously discussed, DOE is in the process of outlining the general requirements for renewable energy over the next several years. A multi-year authorization appears entirely consistent with the DOE planning approach. However, annual appropriations and annual program plans must consider within the multi-year planning environment, the technical accomplishments as well as general economic conditions of the preceding year. We are available to discuss the tradeoffs between budget year and multi-year planning requirements at your convenience, but do certainly recognize the potential stabilizing influence of a multi-year authorization.

## QUESTIONS FROM THE MINORITY

**Question 7: The Committee will probably hear testimony during the FY 1985 budget cycle on the proposed construction of a 100 MW central receiver powerplant. Would the DOE propose to become involved in any fashion with this project? If not, why not?**

**Does the Department believe it would be necessary to support any large-scale component development for this project?**

Answer: In the event the private sector were to proceed with the design and construction of a commercial size (30 MWe - 100 MWe) Central Receiver Power Plant, the Department would seek to have an indirect involvement in the project. The scope of this involvement would include participation in design reviews, engineering definition, and the availability of the Central Receiver Test Facility for critical path tests. However, the Department would not seek to have a direct role, such as cost-sharing in the project itself.

The Department is presently supporting on a cost-shared basis the design test and characterization of a second generation molten salt receiver (repowering category B). Successful completion of this activity should reduce near term technical risks and provide the private sector with the impetus to proceed to construction of a commercial power plant on their own.

QUESTIONS FROM THE MINORITY

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| Question 8: | The Committee understands that the Arizona Public Service Commission has recently submitted a proposal to DOE to develop the molten salt solar thermal technology.<br>What is the Department's position on this proposal? |
| Answer: | Arizona Public Service (APS) has not submitted a proposal to the Department to develop molten salt solar thermal technology. However, we have been informally told that APS is preparing a proposal for submission this spring. If such a proposal is submitted, the Department would evaluate the proposed effort in accordance with the guidelines for the acceptance and review of unsolicited proposals. |

## QUESTIONS FROM THE MINORITY

Question 9: The Department proposes in its budget request to continue to support the operation of the 10 MW central receiver power plant in Barstow, California.

Of the $7M requested for central receiver systems test and evaluation, how much will be specifically allocated to Barstow and how much to CRTF?

What are the Department's long-range objectives for the Barstow project? Does the Department have any plans to convert the Barstow project into a test bed to be used for other solar central receiver technologies?

Answer: The Department's budget request for FY 1985 provides adequate funding for both the 10 MWe Central Receiver Pilot Plant and the Central Receiver Test Facility. $4.5M has been requested for the Pilot Plant which includes provision for the operation and maintenance of the facility and completion of test and evaluation phase documentation. $1.3M has been requested for the operation of the Central Receiver Test Facility.

The 10 MWe Pilot Plant will complete its second year of the test and evaluation phase in August 1984, followed by three years of power production in a typical grid-connected utility mode which will be completed in August 1987. DOE is evaluating a range of options regarding the Barstow facility after completion of the power production phase.

QUESTIONS FROM THE MINORITY

Question 10: Would you please provide the Committee with a programmatic history of the small community solar dish experiments program?

What are the Department's plans for this program for FY 1985, and what does the Department intend to specifically accomplish at the Osage test site?

Answer: The Small Community Solar Experiment (SCSE) Program was initiated in 1977 when Congress appropriated funds to build an experimental solar power plant that would be the first step in addressing the needs of small communities. In October of 1979, DOE requested expressions of interest from small communities in participating in such a program using parabolic dish electric technology. Project size was envisioned at 1 MWe. By January of 1980, 44 communities had responded and in June of 1980, DOE selected six finalists: Wickenberg, AZ, Molokai, HI, Osage City, KS, Harbison, S.C., Burke, S.D., and Cheney, WA.

In parallel, during the first quarter of FY 1980, the Jet Propulsion Laboratory awarded a competitive contract to Ford Aerospace and Communications Corporation (FACC) for the design of the 1 MWe parabolic dish power plant. For the system, FACC selected the Barber Nichols Organic Rankine Cycle engine, the GE low cost concentrator concept, and a cavity receiver.

Osage City was later selected to be the site of the first experiment with Molokai as the alternate choice. The Congress in FY81 and FY82 appropriated a total of $4.6M for the effort. During FY 1982, DOE decided to proceed with a 100 kwe plant, a size considered sufficiently large to satisfy most of the technical objectives of the experiments while meeting the intent of Congress to minimize costs. FACC was directed to design the smaller plant. At that time, FACC changed the concentrator contractor from General Electric to Acurex. Development proceeded on the Organic Rankine Cycle engine, but mechanical and electrical problems were encountered that delayed the schedule and increased costs. In November of 1983, DOE terminated the contract. This left the Osage City project without a system contractor.

In the FY 1984 appropriation, the Congress provided $4.0M for a second SCSE. DOE selected Molokai and in December 1983 released a PON to select system contractors for both Osage City and Molokai. The PON provided a maximum of $4M for the system for each site (total of $8.0M). The PON closed February 29, 1984 with contractor selection anticipated mid-summer 1984.

From these two experiments, DOE expects to obtain performance and operation and maintenance data on the multi-module system in a small utility environment. Previous work has been on single modules in an R&D environment. Of particular importance will be multi-modular experience gained on controls and control strategy.

No funds are requested in FY85 specifically for the SCSE Program. However, ongoing activities in the base dish-electric program on engines, receivers, concentrators and materials research directly supports the two SCSE projects.

QUESTIONS FROM THE MINORITY

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| Question 11: | The Department has recommended $3.1 million for the regional biomass program for FY 1985. How will this funding be allocated among the regions, and do these regions have programmatic plans in place to obligate these funds?<br>If so, would you please outline these plans, indicating funds that will be earmarked for biomass resource assessment activities, the evaluation of inhibiting factors, etc?<br>Have any of these activities also been undertaken by non-federal entities? |
| Answer: | The FY 85 funding will be allocated approximately as follows: $30K will be distributed for each state within three regions to conduct state-specific activities on a cost-shared basis; remaining funds will be used to support private sector initiatives in biomass energy technology transfer that result from competitive solicitations. Under solicitations issued by several of the regional programs, awards have been made to private companies to enable them to undertake research aimed at encouraging biomass energy use. These awards have been made in the past few months; hence, research activities have only recently begun. Awards have been made in such areas as resource assessment, residential and industrial emission controls, biomass fuel standards, forest residue recovery, and the conversion of biomass. Specific regional technology plans are being prepared and will be available in late FY 84 or early FY 85. |

## QUESTIONS FROM THE MINORITY

Question 12: In the wind energy area, please give the status of the following projects and the Department's long-range plans for these projects:

a. The Mod-2 wind energy farm;

b. The Mod-5A program (Does the Department believe it would be appropriate to support the completion of the design package for a Mod-5A machine, and if not, why not?);

c. The Mod-OAs; and

d. The small systems test center.

What is the Department's evaluation of the operating performance of the test center at Rocky flats?

Has the Department considered transferring the test center to another site, and if so, what are its conclusions?

Answer: Operation and research testing of the mod-2 cluster will be continued in FY 85, with funding provided under the DOE Aerodynamics Research and Structural Dynamics Research budget elements and with some cooperative support by EPRI and Bonneville Power Administration. The Mod-5A project is being closed out; however, using funding already allocated to the contractor, summary design documents and research reports on ongoing experimental efforts will be completed and published. Negotiations are continuing with the Mod-5B contractor; if adequate cost-sharing can be obtained this project will be continued. The Mod-OA's served an important role in providing data on interconnection of wind turbines with various types of utility grid networks. More than 38,000 hours of testing was successfully completed on the four machines, representing good examples of very early wind technology. These machines are now being dismantled. The small systems test center at Rocky Flats is a unique facility offering capabilities and services not otherwise affordable to the predominantly small business organizations comprising the small and intermediate wind industry. Its continued operation for wind program research and industry fee-paid testing is proposed for FY 85. Both recently and in the past, other sites have been considered for placement of the test center. The existance of a desireable wind regime and the extent of investment in existing staff and unique inplace facilities are the main reasons for retention of the Rocky Flats test center at the present location.

## QUESTIONS FROM THE MINORITY

QUESTION 13: As you know, the Energy Research and Advisory Board has issued a report on Solar Energy R&D needs and objectives.

To what extent has DOE implemented the recommendations of ERAB in this area?

Do you believe the DOE budget request is consistent with the recommendations of this report?

ANSWER: ERAB examined a broad number of R&D options in each of the seven solar technologies which included: photochemistry and basic research, photovoltaics, solar thermal, wind, OTEC, biomass and buildings. Although the panel found a wide spectrum of promise and potential, some options within technologies were found to be either close to commercialization requiring minimal support or showing little promise and not warranting Federal support.

Over the past few years DOE has realigned its priorities based on a number of considerations including the recommendations proposed by ERAB. DOE believes the FY 1985 Presidential Renewable Energy Budget Request is consistent with the major recommendations of ERAB.

## QUESTIONS FROM THE MINORITY

Question 14: What is the status of the OTEC pilot project program?

What have been the results of the work to date, and have they influenced the Department's position with respect to continued funding of later phases of the OTEC pilot program at some date in the future?

Answer: The 40 megawatt OTEC pilot plant project has completed conceptual design and is mid-way through Phase II, the preliminary design phase. Significant progress is being made towards an economically and functionally sound design. The contractor has stated in several public forums, including the recent OTA sponsored workshop on OTEC, that the pilot plant venture is expected to be a profitable undertaking and that government participation in further phases of the project is not needed. This reinforces DOE's position of concluding direct support upon completion of the current phase. However, this first pilot plant would not be expected to achieve the performance or economics of which OTEC is believed capable. Thus, indirect support in the form of a government funded R&D program on ocean thermal energy, which can provide a technology base for further industrial developments, is proposed with the FY 85 budget request.

## QUESTIONS FROM THE MINORITY

Question 15: The Department recommends $2.2 million in solar technology transfer for CAREIRS.

Does this budget request reflect an increased use of this service?

In determining this recommended level of funding, does the Department believe many of the activities previously undertaken by the EES will not be performed by CAREIRS?

Answer: The $2.2 million budget request for CAREIRS reflects an anticipation of increased use in FY 1985. In determining the level of this request, the Department has not examined potential tradeoffs between the activities of CAREIRS and the Energy Extension Service (EES).

## QUESTIONS FROM THE MINORITY

Question 16: There has been some discussion on the fact that there are many national laboratories actively involved in the DOE solar program.

What is the Department's position on the possibility of consolidating some of these activities at one central location such as SERI?

Answer: Past accomplishments in solar energy research have created the need to evaluate DOE field responsibilities generally, and in particular the future programmatic direction and emphasis at SERI. This evaluation process, which is based on a number of considerations, could lead to improved cost effectiveness through streamlining field program management of solar energy research. As a lead laboratory, SERI would provide the Nation a focal point for solar R&D and establish a basis for the formulation of a research center of excellence in the area of solar technologies without compromising the Department's ability to selectively fund activities at other laboratories having unique facilities or eminent expertise in key areas of investigation.

QUESTIONS FROM THE MINORITY

Question 17: As you are aware, the Committee has been extremely interested in the Heber geothermal binary demonstration project?

Is this project proceeding on schedule, and when do you plan for this project to become operational?

Have there been any problems to date with this project?

Answer: The Heber project is proceeding quite well. It is approximately 11 months behind the original schedule, based on the cooperative agreement signed in 1980. However the project schedule is updated at least annually. The initial delivery of hot brine to the plant will be in November, 1984, and the "turbine roll" (first production of power) is scheduled for March, 1985. Full power and the beginning of the two year demonstration period should begin in March, 1986.

There have been no major problems to date in the project.

## QUESTIONS FROM THE MINORITY

Question 18: The Department has recommended $5.5 million for the hot dry rock program for FY 1985. What have been the problems to date with the final phase of the Fenton Hill project, and do you believe these have now been addressed?

Are the foreign countries involved in the HDR program continuing to provide appropriate financial support?

Do you believe it is premature at this time to consider the possibility of supporting a more-commercial scale project?

If so, why?

What are the Department's plans in the future to identify other possible sites for HDR development?

Answer: The central problem with the Hot Dry Rock project at Fenton Hill, NM has been the inability to connect the two deep wells by hydraulic fracturing. In December, 1983 nearly six million gallons of water were injected into the hot granite rock surrounding the lower well. A huge fractured region was produced, measuring approximately one half mile in two dimensions and nearly one quarter mile in the third. Although measurements of its location indicated that the fractured region surrounded the upper well, no measurable liquid connection was made. It has been concluded that the best method to make the connection is to redrill the lower portion of the upper well so that the new portion passes through the dense fracture regions of this newly created reservoir. Two unknowns remain: what the final resistance to water circulation will be, and how thoroughly the circulating water will pass through the entire fractured volume. If the entire volume is available for heat exchange, it is estimated that it is capable of delivering from 20 to 40 thermal megawatts for ten years, equal to as much as the energy content of 2 million barrels of oil.

Both Germany and Japan continue to supply not only significant financial support ($2.5 million annually from each country) but also invaluable technical and scientific support through the assignment of very capable staff to work as part of the Fenton Hill team. In September, 1983, the three partners signed an agreement to extend until at least October, 1985, the present effective cooperation.

Although there is great optimism that the Fenton Hill project will ultimately be successful, prudence would dictate that Fenton Hill experiments should be completed prior to discussing an even larger and more complex project.

Several years ago the Department conducted a nation-wide survey of hot dry rock resources as part of an effort to measure the ultimate energy potential of this technology. Those surveys revealed several very promising locations for hot dry rock exploitation in the future. Among the very best are Roosevelt Hot Springs in Utah and the San Francisco Peaks north of Flagstaff in Arizona.

## QUESTIONS FROM THE MINORITY

Question 19: The Department has recommended $3.5 million this year for the geopressured resources program.

Has the Department given any thought to consolidating this program with its other unconventional gas resource program activities, and if so, what are its recommendations?

Answer: The Department has carefully considered the merger of the two technological programs. At this time the Geothermal Geopressure program focuses on the research and analysis of data from the three deep design wells where fluids are under high, lithostatic pressure with the goal of optimizing energy recovery from mechancial, thermal and chemical resources. The fossil, non-conventional gas program focuses on much shallower reservoirs under hydrostatic pressure. These two technology programs are integrated and coordinated. The Department does not believe that the two programs should be combined at this time.

## QUESTIONS FROM THE MINORITY

QUESTION 20: As we are all aware, through the years there have been numerous studies projecting the role that renewable energy resources can play in meeting the Nation's long-range energy needs.

What are the Department's recent projections on the energy contribution from renewable resources under current world oil price projections by the year 1990? 2000?

Which renewable technologies show the greatest promise in helping to contribute to the Nation's energy needs within the 1985-2000 year timeframe, and does the Department believe that its budget request is consistent with the priorities reflected in the energy potential of these technologies?

ANSWER: Recent experience confirms that energy forecasts of any type are subject to a great deal of uncertainty. This uncertainty is particularly relevant to a family of emerging technologies such as renewable energy, which includes individual technologies which are either within the research and development cycle or for which industry has begun commercial deployment. Renewable energy forecasts are further complicated by the sensitivity of the technologies to variations in the natural resource, energy demand profiles, and variations in the price or availability of conventional fuels. Accordingly, current renewable energy forecasts should be viewed more as informed judgements of potential than as precise estimates, especially until the cost and performance boundaries of the major renewable energy options are better established through research and development.

ANSWER 20: Within this context, the Fourth National Energy Policy Plan (NEPP-IV), which employs relatively conservative renewable energy assumptions, estimates that contribution of renewable energy to the Nation's primary energy supply system will grow to approximately 10.0 quads by the turn of the century. This increase (from 8.5% of national supply in 1982 to 10.7% in 2000) would occur primarily in the areas of Hydro/Geothermal, Wind, and Biomass. NEPP concludes that renewable primary energy supply contribution would be more balanced across the technology options and would reach approximately 13.1% (13.5 quads) of national primary energy supply by the year 2010.

DOE believes it is premature to presently declare winners or losers among the renewable energy technologies, especially considering the remaining uncertainty regarding their cost and performance potential. The Department has considered current estimates of potential, such as those contained in NEPP-IV, together with a number of other factors (e.g. the degree of remaining scientific or technical risk, the degree of industrial development, etc.) in formulating its FY 1985 budget proposals for these technologies.

# FISCAL YEAR 1985
# DEPARTMENT OF ENERGY
# AUTHORIZATION

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## WEDNESDAY, FEBRUARY 29, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Development and Applications,
*Washington, DC.*

The subcommittee met, pursuant to recess, at 9:34 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the subcommittee) presiding.

Present: Representatives Fuqua, Harkin, Nelson, Schneider, and Lewis.

Also present: Representative Skeen.

Mr. Fuqua. The subcommittee will be in order.

Today's hearing will involve two very successful programs that have received a great deal of attention from the committee. The first is the industrial energy conservation program, which examines ways to improve the efficiency of industrial processes and utilize waste heat and materials that would otherwise be discarded. It is one of the only programs in the Government which funds research aimed at improving the productivity and competitiveness of U.S. industry.

One particular industry that has been of special interest lately to Congress and the American public is the steel industry. Last year, at the request of the Senate, the Department of Energy began a pilot project to demonstrate a new technology for producing strip steel by direct casting. This new process could put the U.S. steel industry back in the forefront of international competitiveness.

We have a number of experts on our first panel who can discuss the direct casting project and the indusrial energy conservation program. We also have a witness from Oak Ridge National Laboratory who will discuss a revolutionary new class of alloys developed at that facility which could completely change the approach to high-temperature materials.

The second panel deals with photovoltaics. In the last 7 years, we have seen enormous improvements in this technology, in part due to the judicious use of research and development funds. Costs have been reduced by a factor of ten. Efficiencies have been improved by a factor of five. Now we have six different technologies being pursued which have the potential to meet or exceed the goals set by the Department of Energy.

Although we are facing competition from the Japanese and the Europeans, our Government and industry research programs in this field are very good.

At this point in the record, I would like to place a statement by our ranking minority member, Mr. Winn.

[The opening statement of Mr. Winn follows:]

# OPENING STATEMENT
HONORABLE LARRY WINN, JR.
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
FY 1985 DOE AUTHORIZATION FOR CONSERVATION
AND SOLAR ENERGY
FEBRUARY 29, 1984

MR. CHAIRMAN, THANK YOU FOR THIS OPPORTUNITY TO EXTEND A WELCOME TO OUR WITNESSES TODAY. THIS HEARING CONTINUES OUR DISCUSSION ON CONSERVATION AND RENEWABLE ENERGY PROGRAMS. I AM PARTICULARLY PLEASED THAT WE COULD HAVE WITH US TODAY THE DEPUTY DIRECTOR OF THE SOLAR ENERGY RESEARCH INSTITUTE, GOLDEN, COLORADO. THE INSTITUTE'S PARTICIPATION IN THE SOLAR PROGRAM, UNDER THE ABLE DIRECTION OF MY FRIEND DR. HUBBARD, HAS BEEN VERY MEANINGFUL AND BENEFICIAL TO THE PROGRAM.

AS I MENTIONED YESTERDAY IN MY STATEMENT THE CONSERVATION AND SOLAR REQUESTS APPEAR TO BE TOTALLY ADEQUATE TO FUND THE APPROPRIATE GOVERNMENT ROLE IN THESE PROGRAMS. THE COMMITTEE CERTAINLY WELCOMES INNOVATION AND CREATIVITY. IF, FOLLOWING THE PRESENTATION OF THIS BUDGET REQUEST, DOE HAS FOUND REASON THROUGH TECHNICAL BREAKTHROUGHS OR RE-EVALUATION TO CHANGE PRIORITIES, WE WILL WORK CLOSELY WITH THE DEPARTMENT TO PROVIDE THEM THE FLEXIBILITY THEY NEED, WORKING WITHIN THE REQUESTED FUNDING LEVEL.

ONE OF THE LESSONS WE HAVE LEARNED IN THE LAST 15 YEARS IS THAT CONSERVATION IS DRIVEN MOST STRONGLY BY THE MARKETPLACE. WE HAVE SEEN THIS NATION'S USE OF PETROLEUM DROP FAR BELOW ESTIMATES MADE IN PRIOR YEARS. ONCE MORE WE ARE GIVEN A CLASSIC EXAMPLE OF THE LAW OF SUPPLY AND DEMAND. HOWEVER, THESE CONSERVATION ACTIVITIES HAVE RELATED TO NEAR TERM TECHNOLOGY. WE STILL HAVE THE RESPONSIBILITY TO DEVELOP HIGH-RISK, LONG-TERM PROJECTS WHICH PROMISE A SIGNIFICANT PAYOUT. WE HOPE THAT THIS CONSERVATION AND SOLAR RESEARCH WILL BE CONDUCTED WITH INDUSTRIAL PARTICIPATION. THE PURPOSE OF SUCH ACTIVITY IS TO DEVELOP A STRONG BASE AGAINST POSSIBLE FUTURE ENERGY UPSET. SO, WE DO SEE THE JUSTIFICATION FOR FEDERAL INVOLVEMENT IN RESEARCH AND DEVELOPMENT RELATED TO CONSERVATION AND SOLAR ENERGY PROGRAMS. AGAIN, IT APPEARS THAT THE FUNDING REQUEST IS AT THE PROPER LEVEL AND I STRONGLY SUPPORT IT.

THANK YOU, MR. CHAIRMAN, FOR HOLDING THIS HEARING WHICH WILL BE HELPFUL TO US ALL.

Mr. FUQUA. In our first panel, we begin with Dr. Lloyd Lawrence of Mechanical Technology, Inc., New York State; Harry Brown, Materials Science Division, EG&G Idaho, Inc.; Dr. Jay Desai, General Electric Co., N.Y., and Roger Carlsmith, Director of the Conservation Division at Oak Ridge National Lab.

Dr. Lawrence, we will beqin with you this morning. As is generally our practice, if you have a prepared statement and you wish to submit that for the record, you may summarize, and we would be pleased to hear you in that fashion.

Dr. LAWRENCE?

## STATEMENT OF DR. LLOYD R. LAWRENCE, JR., DIRECTOR, TECHNICAL DEVELOPMENT, MECHANICAL TECHNOLOGY, INC.

Dr. LAWRENCE. Thank you, Mr. Chairman.

I do request that my written version be submitted for the record. I will make a few brief remarks this morning that are derived from that.

I am Bob Lawrence. I am director of technical development for Mechanical Technology, Inc. As you know, Mr. Chairman, we are about 900 people, a high technology organization headquartered in northern New York, with plants now in various locations in the country.

This morning I am going to address the industrial programs, industrial conservation programs, which you mentioned. We will be recommending those programs for a total authorization and appropriation in fiscal year 1985 of $48 million.

Also, we will be recommending the Department of Energy gas heat pump program to be authorized and appropriated at $7 million.

To start my testimony this morning, I wonder if it would be possible to turn to page 3 of the written version, where there are a variety of figures placed one above the other. I have placed these figures one above the other so that we could read down, in any given column, the year in which these various things have taken place, and put into perspective the need for the industrial programs within the Department of Energy in the country.

First of all, the top figure is our merchandise trade deficit. You can see that this has taken a dramatic turn for the worse over the past few years, and we are now headed through 1984 to an estimated $100 billion balance of trade deficit just in that year.

Our total through 1983 now in balance of trade deficits is $327.5 billion which, if that were still in our economy, operating, working, and being invested, would greatly enhance our national economic strength. As you can see, sir, that $327 billion is pretty close to the number that has been submitted for our defense budget, just for this year.

The more disturbing thing falls right below that, where you can see that the current account, which is actually cash flow into and out of the United States, has now turned dramatically negative in 1982 and 1983 and is headed for even worse figures in 1984. This includes not only the merchandise trade but investments, financing, the services area, and you can see that we have now come to the point where we are no longer internationally competitive in those areas as well.

The third figure is one which you are very familiar with, which of course is our national budget deficit figure.

And finally, I have put a graph here which is not normally shown in conjunction with these others but which I think is terribly significant, and that is the cumulative investment by foreigners in the United States during this time period when we have been uncompetitive and our cash flow is going out of the country.

You can see that we have now reached a total of $225 billion, which is foreign investment in the United States, and if we put that in a perspective by seeing that Getty Oil was purchased for $10 billion, you can readily imagine how much of our national assets, or are former national assets, are now owned by foreign interests.

I would like to point out something which I am sure you are familiar with, Mr. Fuqua, and that is that at the end of World War II, the United States had a national debt which exceeded its gross national product, and it was only by 1949 that those two figures became equal, that the national debt actually came down to the gross national product.

Then in the era of the fifties and early sixties, this was when we came back to economic strength. We did it by producing and selling durable goods worldwide in a fashion where we dominated the world economically in those areas.

We have obviously forgotten our own lesson. The rest of the industrialized world has learned it well, and they put the production of durable goods, international competitiveness, as their No. 1 priority. We can hardly find it in the newspapers today. That seems to be below other things which people are focusing on.

In any event, in this country, we have had a history now, since we have been internationally dominant, of industry and Government having the luxury of fighting with each other and calling each other names and all of these good things which we have all experienced.

There is one exception to this, and that is the industrial conservation program in the Department of Energy, where this particular Government entity has gotten the confidence of industry, has worked very well with industry, and has undergone a number of very significant projects which have enhanced our capability for durable goods production in the industrial sector.

It is an extremely small portion of the national budget aimed at this thing, which I believe should be of highest priority.

If I could read briefly one of my paragraphs here, it goes as follows: It is clear, then, that an investment which enhances our national capability to produce goods has the greatest economic benefit of any investment. It is also clear that a reduction in our balance-of-trade deficit will produce positive cash flow back to the United States, helping employment and our national economic health. It is also abundantly clear that the largest element of our trade deficit continues to be foreign oil.

Therefore, an investment with the highest national benefit attached would appear to be an investment in the goods-producing sector which would enhance our national competitiveness and reduce our dependence on foreign oil. And it is this kind of investment which is routinely made by the Industrial Conservation Office within the Department of Energy.

If I could briefly add two things which do not appear in the charts in my testimony, I recently read the February 27 issue of Newsweek, and there is an article in there which indicates that, for the first time since 1917, we will become a net international debtor in the United States.

Also, you will find that even with all of the tax incentives and benefits which have been put in for industry over the last 3 years, our total industrial profit in the United States is not yet back to the 1979 level. It has, in 1983, just come back to the 1980 level. We have not yet achieved the 1979 level of total industrial profit in the United States.

All these things mean that not only is the DOE industrial program extremely important, but it needs to be greatly enhanced; and that the precedent set by that program needs to be greatly expanded.

Let me address quickly a couple of specific things, Mr. Chairman. In my recommendations that are in the written testimony, there is one line which has become a rather small figure in the grand scheme of things, and that is the advanced steel plant study in which I recommended $1 million.

The purpose of this is to take all of the technology which we have developed in the past 15 years, since the Japanese designed and implemented that Ohgishima plant in Tokyo which propelled them into international steel leadership, that 15 years' worth of technology would be implemented into a design study for a similar U.S. entity, which would be a major steel entity which would, hopefully, put us again into the international leadership. Some of the details of why are in my written testimony.

The other item that I want to point out at this time is the gas heat pump area, where we are recommending $7 million. That area falls under the buildings sector rather than the industrial sector of the conservation budget, but it is terribly important because we are looking at 40 million households that it would affect. If you averaged everything over all the regions nationally, we are talking about 50 percent savings on gas bills implementing this technology.

Over the past few years, we have gone through the technology development at several companies in the United States. We have prototypes working. The Japanese and Germans are investing $10 million per year each in this technology. We need to enhance the DOE level to at least $7 million for the next fiscal year in order to go from prototypes to the kind of testing and development that is necessary.

The other panelists are going to talk in detail about the steel area which, of course, is the major area supporting our international competitiveness in durable goods, and with that, Mr. Chairman, I thank you for the opportunity to be here today to present my testimony.

[The prepared statement of Dr. Lawrence follows:]

# HEARINGS ON DOE CONSERVATION PROGRAMS

Subcommittee on Energy Development and Applications
Committee on Science and Technology
U.S. House of Representatives

Presented by: Dr. L. R. Lawrence, Jr.
Director, Technical Development

February 29, 1984

MECHANICAL TECHNOLOGY INC.

## About the Author . . .

### Dr. L. R. Lawrence, Jr.

Dr. Lawrence is Director of Technical Development for Mechanical Technology Incorporated (MTI). In this position, he is responsible for long-term corporate planning with primary emphasis on productivity, Stirling engines, Rankine cycles, heat pumps, and waste heat utilization. He is actively involved in the development of new markets for high-efficiency, high-reliability equipment. Prior to his present position, Dr. Lawrence was Director, Energy Conservation Research with the Gas Research Institute where he was responsible for the Gas Industry's program addressing the improved end-use of natural gas. He has been an executive with the Energy Research and Development Administration and with the Air Force Office of Scientific Research. In 1974, he was an Air Force Nominee for America's Ten Outstanding Young Men of the Year. He holds a number or professional memberships and has numerous technical publications.

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# Testimony of
# Dr. L. R. Lawrence, Jr.

Mechanical Technology Incorporated
Latham, New York
Subcommittee on Energy Development and Applications

Committee on Science and Technology

Hearings on DOE Conservation Program

February 29, 1984

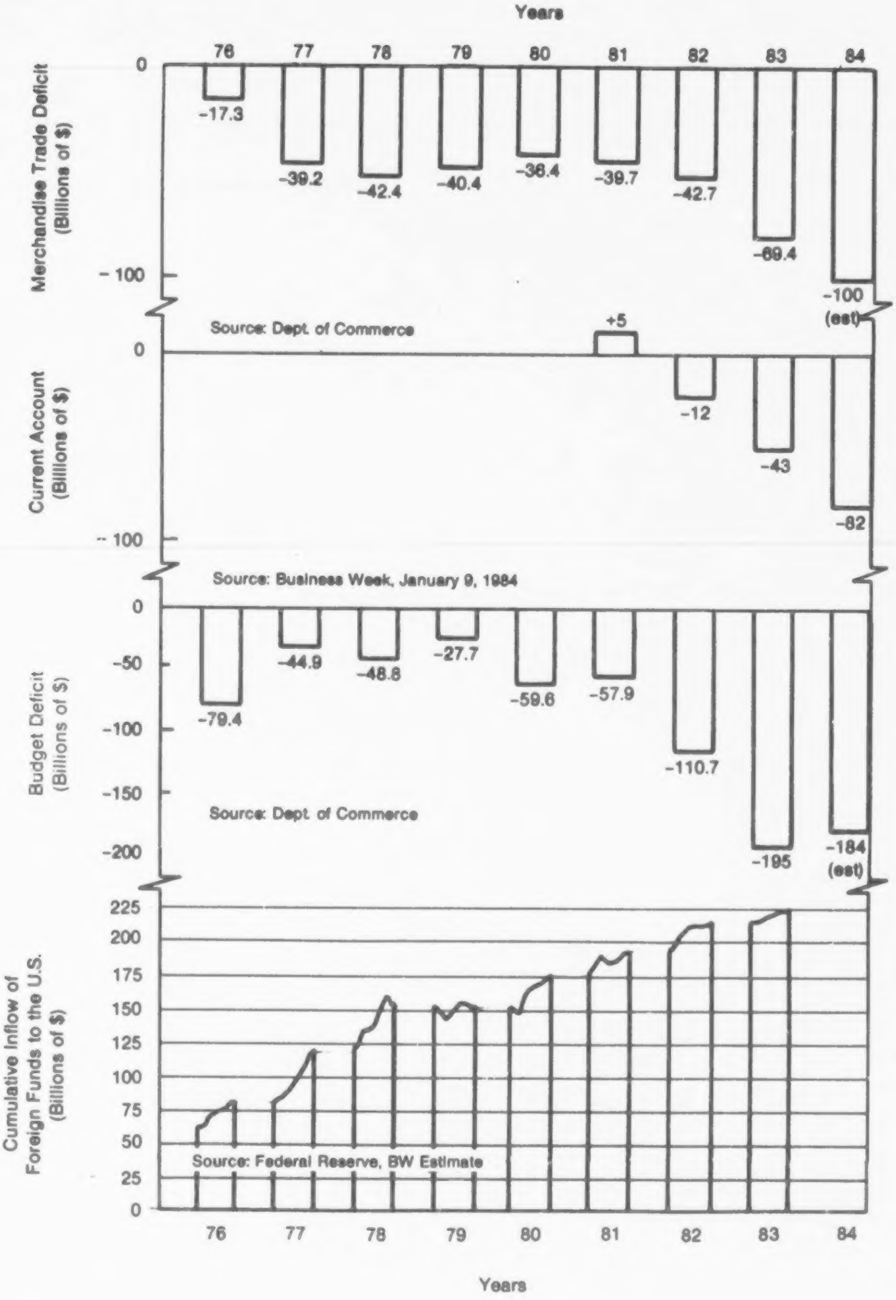
Mr. Chairman and members of the Committee: I am Dr. L. R. Lawrence, Jr., and I am Director for Technical Development of Mechanical Technology Incorporated (MTI). I appreciate the opportunity to come before you today to discuss the relationship between the DOE Conservation Technology programs and the nation's needs in the areas of trade, energy, and productivity. As you know, Mr. Chairman, MTI is a high-technology organization, dedicated to evolving products in the residential, commercial, and industrial sectors from our strong technology core. We are one of the medium-size (900 people), aggressive companies responsible for a large part of the "industrial innovation" which occurs in this nation. We have been successful in commercializing our innovations to a significant extent, and we are most appreciative for the partnership we have had with the federal government in addressing those areas of high risk and high potential which fall outside the normal corporate investment criteria.

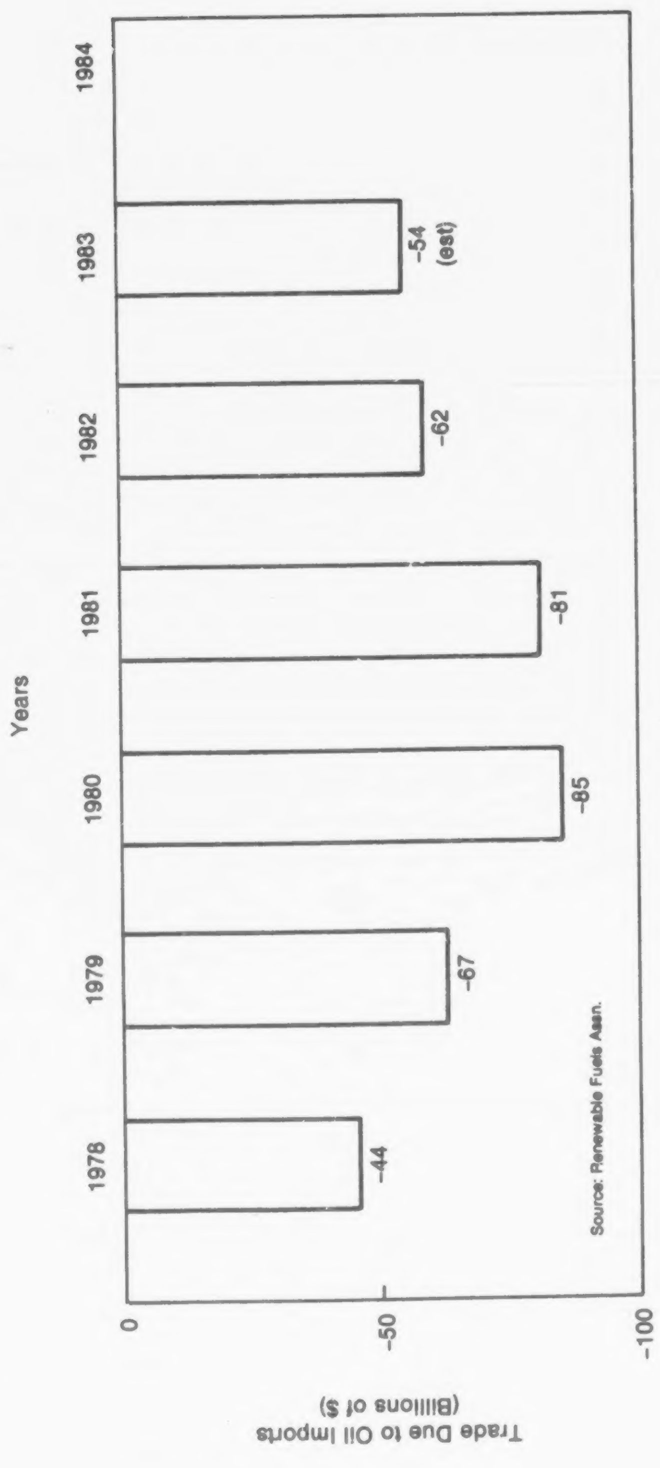
My testimony today will address, broadly, the national economic situation and the major positive role to be played by a well-funded and managed DOE industrial program. I will place some emphasis on the steel industry and make some suggestions which could lead to substantial improvement in this industry. I will also mention the area of gas-fired heat pumps; an item which, when successful in the heating, ventilating, and air conditioning (HVAC) industry, can produce major and substantial national benefits.

I would like to begin my testimony by examining the following figures in parallel. It is intriguing to see the trends over the last few years in Merchandise Trade, and the cost of foreign oil when compared to the current account and the federal budget deficit. In addition, the total foreign investment in the U.S. over the past 10 years exceeds $225 billion. This shows a strong degree of foreign control over our economy which would not be present if the balance of trade had been maintained at even or had been positive. In fact, since 1975, over $327.5 billion dollars have left the control of the United States economy and have come under foreign control through balance of trade deficits. Imagine the positive effect on our employment and federal revenue situation if those funds had remained and were circulating in the United States economy, under United States control.

Until the end of 1981, the balance of trade deficit was rationalized to be inconsequential since the current account (total cash flow in and out of the United States) remained even, or slightly positive. The increase in foreign sale of services (insurance, finance, etc.) when coupled with foreign investment in the United States continued to maintain a cash flow balance at the United States border. However, in 1982 and 1983, even this measure turned sharply negative, showing a strong trend of increasing cash flow out of the United States. This, again, results in overall negative effects on our economy in terms of jobs, revenues, and our projected capability to maintain our national lifestyle.

Turning from these numbers, for a minute, it is worthwhile to note that at the end of World War II, our total national debt equalled our Gross National Product. We recovered from that situation by producing and selling goods, worldwide, with a substantial yearly surplus in merchandise trade. Much of this cash inflow came from producing and selling steel to the other industrialized nations whose industries had been destroyed by the war. Steel and steel-based products, such as vehicle and farm equipment, made up a major portion of overseas sales. Our competition was negligible, and our economy strengthened and prospered from a national cash inflow due to the overseas sale of United States manufactured goods. The rest of the industrialized world learned from this experience; it learned that the maintenance and growth of a strong economy is


Years
76
77
78
79
80
81
82
83
84
Merchandise Trade Deficit (Billions of $)
0
- 100
-17.3
-39.2
-42.4
-40.4
-36.4
-39.7
-42.7
-69.4
-100 (est)
Source: Dept. of Commerce
Current Account (Billions of $)
0
- 100
+5
-12
-43
-82
Source: Business Week, January 9, 1984
Budget Deficit (Billions of $)
0
-50
-100
-150
-200
-79.4
-44.9
-48.8
-27.7
-59.6
-57.9
-110.7
-195
-184 (est)
Source: Dept. of Commerce
Cumulative Inflow of Foreign Funds to the U.S. (Billions of $)
225
200
175
150
125
100
75
50
25
0
Source: Federal Reserve, BW Estimate
76
77
78
79
80
81
82
83
84
Years



Source: Renewable Fuels Assn.

overwhelmingly dependent upon having a positive balance of trade and a positive current account. We have forgotten our own lesson!

After this brief discussion of the need for a positive balance of trade for national economic health, let us now turn to the nation's employment distribution as a function of manufacturing. In its Monthly Labor Review, December 1983, the Department of Labor shows the nation's employment breakout in the goods-producing (manufacturing, mining, construction) and service-producing (transportation, public utilities, wholesale and retail trade, finance, insurance, real estate, other services) sectors. In 1981, 25,497,000 people were employed in the goods-producing sectors of which 20,170,000 were in manufacturing. In 1982, this number dropped to 23,907,000 as manufacturing dropped to 18,853,000 (mining and construction changed only slightly). In October of 1983, the goods-producing sector had recovered slightly to 24,167,000 as manufacturing recovered slightly to 19,040,000; two million people below the record of 21,040,000 employed in manufacturing in 1979 and 26,461,000 employed in the goods-producing sectors in the same year. In the area of services, employment increased slightly from 65,660,000 in 1981 to 65,690,000 in 1982, and 66,900,000 as of October 1983.

Now let us take a brief, simplistic look at the overall national benefit of an increase in manufacturing, an increase in services, and (for added emphasis) an increase in defense production.

When a product is produced, it requires a building, tools or machinery, and employees to produce it. That's just the beginning. It also requires wholesale/retail trade, financing, insurance, transportation, and other services. In other words, a growth in produced goods automatically creates growth in service employment as well. Therefore, a manufactured product has a large economic multiple associated with it!

A service, by definition, services something. A growth in service employment means, simply, that additional things are being serviced. It makes no distinction between foreign or domestic items, and it creates no perceptible additional employment outside of its own sector. It has a low economic multiple asociated with it.

It is widely known that an investment in defense, although often required for basic national survival, is an investment with a low economic multiple. A defense item is generally either parked, stored, practiced with, or destroyed, and does not circulate in the economy. Although it may need to be transported or financed, it does not require wholesale or retail trades, nor is liability insurance required. Product liability is not a military concern. Military sales to overseas entities can help the balance of trade, but the economic multiple is clearly not competitive with a manufactured item for commercial sale and use.

It is clear, then, that an investment which enhances our national capability to produce goods has the greatest economic benefit of any investment. It is also clear that a reduction in our balance-of-trade deficit will produce positive cash flow back to the United States, helping employment and our national economic health. It is also abundantly clear that the largest element of our trade deficit continues to be foreign oil. Therefore, an investment with the highest national benefit attached would appear to be an investment in the goods-producing sector which would enhance our national competitiveness and reduce our dependence on foreign oil! It is this kind of investment which is routinely made by the Industrial Conservation Office within DOE.

Mr. Chairman, industry and government in this country have traditionally been adversaries, especially in those sectors providing commercial goods. In all government, there is only one entity which I know that has overcome this stigma to the point where it is a trusted and respected industrial companion. This entity is the Office of Industrial Conservation in the Department of Energy.

The Office of Industrial Conservation has, from the beginning, "done it right." In 1975-1976, I saw this office hire experienced people from industry who know the problems "in the trenches." In their new position within government, these people continued to interact strongly with the industrial sector. Their doors have always been open to people from the private sector, and they have taken in and analyzed a multitude of ideas which came from the industrial sector, funding those which they considered the best, as funding was made available. They have also, nearly always, demanded cost share to ensure that the corporation was solidly behind its contractual activity. The results over the last eight years speak for themselves and are published in a document entitled "The DOE Industrial Energy Conservation Program; Project Description Sheets." This is a publicly available document from DOE. I am providing a copy of it as a file copy to be placed in the Science and Technology Committee backup file for this hearing.

Mr. Chairman, I would suggest that the federal investments made by the Industrial Conservation Office are providing nationally beneficial results in goods-producing competitiveness, eventually resulting in lower energy use, reduced trade deficits, higher employment, and higher federal revenues. It could be argued that an investment by this office into the industrial high economic multiple sector can pay for itself in a short time. This will happen if, in fact, the economic multiple for this investment, in a given year, is four, taxed at an average of 25%. Therefore, not only do we strengthen the nation with this kind of federal investment, but it can be argued that we even quickly get our money back!

In short, Mr. Chairman, if there is any part of the federal budget deserving of as much increase as it can creditably absorb, it is the DOE budget in energy-efficient technologies; particularly those programs funded by the Industrial Conservation Office. For FY85, I would recommend, specifically, the following dollar allocations:

| | |
|---|---|
| Waste Energy Reduction | $14.0 M |
| Industrial Process Efficiency | 14.0 |
| Industrial Cogeneration | 5.0 |
| Implementation and Deployment | 4.0 |
| Program Direction | 3.0 |
| Thin Strip Casting | 7.0 |
| Advanced Steel Plant Study | 1.0 |
| | ------- |
| TOTAL | $48.0 M |

Many of these areas have been discussed in detail in past years before this Committee. There are two fairly new ones, however, which deserve special attention today. These are the Thin Strip Casting effort and the Advanced Steel

Plant Study. To put these areas in perspective, I am going to make a few brief summary remarks concerning the steel industry.

The recent book by Bolling and Bowles entitled "The Competitive Edge" gives an excellent, short, readable overview of the nation's steel industry. The book depicts steel industry problems as a function of its history, and has an excellent chapter entitled "The Steel Industry: Opportunity for Revitalization." A key paragraph from this chapter reads:

> "In 1973, both Japan and the United States were hit with the price impact of the oil embargo. As energy prices shot up, so did the basic cost of steel in both the United States and Japan. Because Japan is resource poor and imports most of its energy sources, its industry had been conscious of energy costs during modernization. As might be expected, Japanese plant and equipment was far more energy-efficient than its United States counterpart. Basic costs - including oil, coal, natural gas, and electricity - were brought under control in 1975 and 1976 in the Japanese steel industry. They were not in the United States. Thus, a weakened position in energy completed the weakening of our economic triangle and contributed to the American steel industry's relative decline. The United States steel industry was not world competitive and was on the verge of partial liquidation by the end of 1976. Driven by higher energy costs and lower productivity in the United States, steel imports reached a new high of 19.3 million tons in 1977."

A final piece of background is presented from the journal of Japanese Trade and Industry: No. 6, 1982, pg. 28. In this Journal is a description of the Ohgishima Steelworks, owned by Nippon Kokan K.K. That brief description follows:

## Ohgishima Project - A Model Steelworks

During the 70 years since its foundation, Nippon Kokan K.K. (NKK) has undertaken many projects in keeping with the needs of the times. One of the most important examples was the construction of the Ohgishima complex with an annual crude steel capacity of 6,000,000 tons.

NKK's Keihin Works in Kawasaki suffered from various problems, including its proximity to urban areas, the small site, dispersed siting of manufacturing plants and superannuation of production facilities.

The Ohgishima project was designed to revitalize the Keihin Works. The project called for replacing the major facilities with a giant steelmaking complex on man-made Ohgishima island in Tokyo Bay. The land was reclaimed with 8.5 million cubic meters of earth - more than that dug to build the Suez Canal. The project, undertaken from 1971 to 1979, may be the last case in this century of an integrated steelworks being built completely from scratch in Japan.

In the past, most integrated steelworks construction in Japan was aimed at boosting production capacity. The Ohgishima project was an epoch-making undertaking in that it was aimed at increasing the efficiency of plant operation and preventing pollution.

The Ohgishima complex has the following three major features:

(1) Rational plant layout, up-to-date production facilities and high-level production control system.

In Ohgishima, the transportation system for raw materials and products is fully streamlined in a linear flow from east to west. Greater automation has been achieved through the adoption of up-to-date facilities for operations ranging from raw materials handling and transportation to pig iron production, steelmaking and rolling processes, and power generation. The plate mill can manufacture products of up to 5.3 meters in width and the hot-strip mill up to 2.3 meters, both the largest in the world.

The hot-strip mill is also a revolutionary plant, with the world's first automated slab and coil yards.

As for production control, on-line computer control covers operations ranging from the receipt of orders to final shipment, ensuring customers of high product quality and delivery exactly on schedule.

With these advantages the Keihin Works has emerged as an outstandingly efficient steel plant. Productivity (crude steel output per plant worker) nearly doubled from 240 tons in 1967 to 410 tons in 1981.

(2) Energy-saving measures

A. Representative of energy-saving facilities in the production process is its continuous casting lines which are important as well from the viewpoint of conserving resources. The continuous casting rate has been rising recently in Japanese steelworks. At the Keihin Works, the rate rose from 53% in 1978 to 90% in 1981.

B. Most energy generated within the complex, such as gas, heat and pressure, is recovered for effective utilization. All energy is centrally controlled by computer.

(3) Pollution prevention measures

About 20% of the total $36 million investment in the complex went to pollution prevention measures, such as minimizing the emission of SOx, NOx and dust. Efforts were made to improve the environment of the working site and neighboring areas.

NKK's Ohgishima project is a model of steel plant construction, an ideal example of a steel mill sited near an urban area and of the modernization of aging steelworks.

* * * * *

Mr. Chairman, the key point to be made is that the Ohgishima Steelworks was begun 15 years ago. In that 15 years, we in the United States have evolved a number of key technology improvements which, if implemented on a broad scale, could supercede the capabilities of Ohgishima. We need, however, to be smart enough to see the opportunity and seize the initiative. This then leads to two key projects:

Thin Strip Casting ($7M). This area will be discussed in detail by a number of other witnesses at this hearing. Therefore, I will limit my remarks to the following:

- The process, if successful, can save substantial energy and cost in the production of steel products which make up nearly 50% of the steel market. The process would eliminate the reheat furnace and the hot mill used in present thin-strip production. The hot mill is generally the biggest investment within a steel mill and has the lowest reliability. Therefore, elimination of the hot mill eliminates the biggest item in both fixed costs and operating costs.

- For once, the Japanese do not yet have this process. This is a chance for us to "leap-frog" the competition.

- Feasibility studies were completed in January 1984, and the project is now ready for significant development funding.

Advanced Steel Plant Study ($1M). Mr. Chairman, Ohgishima steelworks was begun 15 years ago. Now it's our turn. The $1 million to be spent on this study would address the feasibility and conceptual design of a major steel-producing facility which would produce 6 to 8 million tons annually. It would incorporate the lastest technologies such as Direct Smelting, Hierarchy Computer Control, Advanced Sensors, and Thin Strip Casting. It would be placed in a location such as offshore on a man-made island in Lake Erie, allowing ore boats to unload on one end of the island and finished products to leave from the other end via boat or causeway. Financing and ownership options should be examined including optional roles of government. The latest pollution control technology would be employed. In short, this study would integrate the best available and developing steel technology into an entity which would, once again, put our nation into the forefront of steel production; an area with a very high economic multiple.

This ends my discussion of DOE's industrial program.

GAS HEAT PUMPS ($7M - FY85).

I have one other subject to address today, Mr. Chairman, if I may be allowed. That subject is heat pumps which operate from natural gas or fuel oil. These are generally referred to as Heat-Activated Heat Pumps or Gas-Fired Heat Pumps. For FY85, this area requires $7 million.

In the United States there are 40 million single family residences which utilize gas as a source of heating fuel. Thermal heat pumps burn conventional fuels such as natural gas to produce space heating and cooling at exceedingly high efficiency. Compared to the best possible combustion furnace systems, thermal heat pumps offer the potential to realize significant energy savings of up to 4.5 Quads of Energy in the United States residential sector and to provide enhanced security during sudden fuel dislocations.

The Japanese and German governments have initiated significant programs in excess of $10 million per year directed toward developing both the long and near term technology options to capture the potentially large worldwide market. Comparable development efforts need to be pursued in the United States to forestall foreign competition and to ensure that American industry will be able to compete in domestic and foreign markets for heating equipment customers during the late 1980s and 1990s.

The Gas Research Institute, reacting to industry pressure, has elected to place an increasing emphasis on low risk technical options. However, greater national benefit could be achieved from the more advantageous operating characteristics associated with advanced, longer term options.

Several attractive long-term technologies have been identified as having significant potential to succeed in the residential sector. Specifically, free-piston Stirling engines, free-piston internal combustion engines, and double effect absorption cycles show a good probability of providing the reliable, long-life, high-efficiency operation required of heat pump systems. Based on their relatively early stage of development, it is not evident which technology has the highest probability for long-term success. Therefore, multiple program paths need to be pursued to ensure a reasonable chance for achieving success.

Due to the high technical risk associated with long-term heat pump options, private industry cannot bear the long-term development costs. The burden of development needs to be supported by public funding.

Previous levels of public support are not sufficient to insure that American industry will be technologically able to thwart future foreign competition. In FY85, the United States Heat-Activated Heat Pump Program requires $7 million in appropriations of which $6 million would go to prime contractors, and $1 million would be used by DOE and Oak Ridge National Laboratory for management and supporting research. With these funds:

- The critical technologies required for reliable long-life in heat pump prime movers will be developed.
- Laboratory prototypes will be designed leading to fabrication of units that will verify the efficiency potentials of the various options.
- Critical components will be developed for reduced fabrication costs.
- Supporting research will be conducted on materials, fluids, dynamics, and mass and heat transfer.

This program is vital to America's long-term interests in the residential equipment market, and needs to be strengthened and accelerated in order to ensure that we maintain a competitive edge in the domestic residential market and preserve future opportunities in the international market. Success will provide an improved standard of living for many Americans, an improved balance of trade, conservation of resource, and enhanced employment opportunities.

## Conclusions

Watching the FY85 budget process, Mr. Chairman, the casual observer notices a tug-of-war between expenditures for enhanced defense and funds for social welfare; two sectors with decidedly low economic multiples. Being almost completely neglected is that sector which has played a major role in pulling the country out of prior economic difficulties: the high economic multiple, goods-producing sector. While we build our defense capabilities, foreign interests control more and more of our cash and our industrial base. While we defend against foreign military takeover, we are experiencing a gradual, foreign economic takeover. Clearly beneficial areas for federal expenditure are those areas of high economic multiples, on projects which are energy conserving, cost reducing, of substantial projected benefit, and including either risks, costs, or payback times which make private sector investment unattractive. The Conservation Technology Programs in DOE are clearly such investments and should receive maximum federal attention.

Mr. Fuqua. Thank you very much, Dr. Lawrence.

Mr. Brown, we will hear from you next.

## STATEMENT OF HARRY L. BROWN, MATERIALS SCIENCE DIVISION, EG&G IDAHO, INC.

Mr. Brown. Thank you, Mr. Chairman and members of the subcommittee.

I wish to have my written testimony submitted into the record. I will quote from it to some extent.

We have been asked for our views on the Federal role in conducting research and development related to industrial energy conservation. Our comments are presented from the perspective of EG&G Idaho, Inc., prime contractor to the Department of Energy at the Idaho National Engineering Laboratory, from here on referred to as INEL.

We at the INEL have participated in the Department of Energy's Office of Industrial Programs [OIP] energy conservation activities in both technical support and, to a lesser extent, R&D performance capacities for over 7 years.

Our general remarks will note the industrial program accomplishments and how they have been achieved and suggest how the Federal role can be enhanced for future accomplishments. We will then discuss the thin-strip steel casting project efforts which are an excellent example of this enhanced Federal role.

Since its inception, DOE's OIP has sponsored nearly 200 projects in research and development of new, high-risk, high-potential technologies for improved energy productivity. Of these projects, about 15 percent have been completed. The resulting process and hardware improvements are penetrating the industrial markets and are already saving over 21 trillion Btu annually—over $100 million at current prices.

Energy conservation is often characterized as the cleanest, easiest, cheapest way to ameliorate the consequences of uncertain energy supplies. Sustaining the rate of energy productivity increase for the Nation will require the continuing development of new and innovative technologies. The development of these technologies will be somewhat more expensive than past efforts, but the benefits to the Nation will be more than proportionately greater.

No developed technology can save energy in industry until it has been implemented by industry. The industrial conservation program is uniquely positioned to support research and development activities in which Government and industry share the cost, risk, and benefits.

The cooperative approach to energy research has been successful. Close liaison with management and technical personnel in the private sector has been established and maintained by DOE–OIP. As OIP places increasing emphasis on higher risk R&D initiatives, the technology being developed will be more responsive to national needs than to those of specific industries or firms.

There is therefore a need for increased Government/industry cooperation. One must then consider the value of an enhanced team approach in industrial energy conservation.

This approach should continue to emphasize three vital elements of the Federal role: first, energy program initiation; second, conduct of portions of the R&D project effort; and, three, technology transfer to the industrial public.

Increasing reliance must be placed on Government-initiated programs and projects for innovative, longer term, higher risk, higher cost, broad-application R&D.

Because of the need for increased Government/industry cooperation, it may be necessary to arrange for performance of R&D by organizations other than the private sector. DOE should enhance the existing cost-shared industry approach with Government and Government-supported cooperative R&D.

Finally, a vigorous technology transfer effort is needed to enhance and supplement present methods. The Federal Government already has, in its national laboratories, the facilities and expertise to put into effect these enhancements. These laboratories are a national resource and should be more fully utilized. In the industrial conservation program, use is being made of the Idaho National Engineering Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory to provide essential technical support.

Such services include field management, evaluation of proposals, contract procurement and administration, technology assessment, and program planning. It may now be appropriate to expand the supporting role of the national laboratories, in cooperation with industry, in formulation of Government-initiated programs for innovative technologies, design and conduct of appropriate R&D activities for which the Government should be responsible, and technology transfer to the scientific and engineering communities for industrial application.

We at the INEL stand ready to play a greater role in industrial energy conservation R&D.

As a part of this testimony, we have been asked to discuss the thin-strip steel casting program managed by the Idaho Operations Office of the Department of Energy. This project serves as an example of the enhanced approach. It was Government initiated and, though still in an early stage of development, has already involved the cooperative efforts of DOE, private industry, academia, and national laboratory personnel.

Energy use in the United States for 1983 is estimated at 70 quads. Of this, 35 percent, or 25 quads, is for manufacturing. In the manufacturing sector, metallurgical processes are large energy users, about 15 percent or 5 quads, because of the elevated-temperature operations.

The first industrial applications of continuous casting occurred within the last 40 years. This technology produces sections of 4-inch or greater thickness and, more recently, very thin materials, less than ten one-thousandths inch, have been produced by continuous casting techniques to meet special requirements.

The thicknesses of concern for steel sheet and strip, typically 0.030 to 0.187 inch, are well outside the capabilities of the two existing continuous casting technologies. Our present concern is to bridge this gap. The potential energy and economic savings are large, and success may help greatly in revitalizing the American steel industry to compete with foreign sources.

Thirty million tons of relatively thin sheet and strip are currently produced annually in this country. The majority of this material goes into cars and appliances. Substantial amounts of energy are needed to make these products from heavy sections. Estimates of energy savings from use of continuous thin-strip casting range from 5 to 10 million Btu per ton, depending upon the base process compared. Assuming $5 per million Btu, this represents at least a $750 million saving per year.

The technical and patent literature reveals the interest in this new technology. A number of patents for making commercial steel strip by continuous casting methods were granted within the past 15 years but have not been developed.

Other patents relate to rapid solidification technology for producing much thinner sections than current steelmaking practice. This technology covers several versions of the basic equipment, now used commercially to cast special materials as well as lower melting metals such as alloys of copper and aluminum. However, none of these applications approaches the potential volume and energy savings of thin steel strip and sheet.

A more detailed appraisal of current continuous casting technology is the basis of another presentation today by Dr. Jay Desai.

In July 1982, DOE issued a notice of program interest requesting proposals for concept development and feasibility studies in the area of thin-strip casting. Seven proposals were received. Four were selected for contract negotiations.

Contract agreements, in alphabetical order, are: Battelle Columbus Laboratories, to develop a mathematical simulation model; General Electric Co., to perform evaluation of the current thin-strip production and use picture and current continuous casting technology to permit process selection; Massachusetts Institute of Technology, to perform experimental and analytical studies to assess the single-wheel casting process; Westinghouse Electric Corp., with U.S. Steel Research Laboratory as a subcontractor, to perform experimental and analytical evaluation of planar flow casting.

Three of the four proposals recommended a three-phase program involving: concept development and feasibility studies, phase I; concept selection and experimental characterization, phase II; pilot plant-scale process development, phase III.

All four contractors have recently completed their phase I investigations. Brief synopses of these projects, as well as general conclusions drawn from them, are included as attachment 2 to this statement.

The four studies do not identify a clear-cut choice of one process to pursue. Rather, the two promising options—single and double roller or belt—require characterization on a somewhat expanded laboratory scale to define the advantages and problems of each option.

The necessary follow-on work includes experimental development followed by pilot plant design and operation.

Additional DOE effort dates from June 1982, when an innovative approach to continuous thin-strip casting was conceived by DOE-OIP personnel. INEL scoped and analyzed the thermal aspects of the concept to determine its practicability, and a patent application covering the process was filed by DOE in November 1983.

Although its energy-saving potential is slightly less than other thin-strip concepts, the double-clad thin-strip process has at least two noteworthy advantages. First, it appears to require less technological development for near-term application. Second, it seems well suited for specialty products of high market value.

Further interest in thin-strip casting became obvious with the 1984 appropriations legislation which resulted in the thin strip casting pilot plant project [PPP], and reaffirmed the continuation of related work initiated under the four feasibility study contracts referred to as "phase II and following" pursuant to the 1982 notice of program interest.

In compliance with the intent of this legislation, a solicitation for cooperative agreement proposals, a SCAP, has been issued by DOE. The complementary relationship between the PPP and the phase II and following efforts is being studied by DOE to minimize duplication of work and obtain maximum beneficial input to the overall technology development.

Selection of the winning PPP proposal is scheduled for no later than May 15, 1984. Proposals for phase II and following work will be considered after that date.

The referenced SCAP calls for repayment of Federal funding from the profits of subsequent technology use and licensing. This provision tacitly acknowledges that the industry may presently require financial support in undertaking major development efforts for new technology but emphasizes that the work, to merit support, must have a reasonable expectation of profitable results. Therefore, the Federal support should ultimately be repaid.

It is implicit that Federal support may not cover the entire cost of the work. From the industrial and academic interest already exhibited, we feel that the timing is right for increased development activity in continuous thin-strip casting. The recent feasibility studies and related discussions show both a high level of interest and the availability of basic technology and supporting analyses which may be of value to this development. Further support for our position is expected from the responses to the current solicitation.

With respect to the thin-strip casting initiative, the implications of the Federal role are strong. Our domestic steel industry must be revitalized. Foreign competition can be met only with an equally advanced domestic capability. For our industry to merely pace foreign competition is not effective. A major step forward is needed to give us a technical lead as well.

Our metal industries are handicapped economically because they are not sufficiently competitive with foreign suppliers. Economic problems preclude development of this technology without assistance. The federally funded thin-strip initiative provides the needed assistance on a sound technical and economic basis. The desired role of national laboratories in helping develop the necessary initiatives has already been described.

In summary, the Federal role as we see it involves a broader view and increased effort to push high-risk programs. Past involvement indicates to us that a cooperative effort involving DOE–OIP, industry, and academia, with active assistance on the Federal level by the national laboratories, is the most effective route.

I thank you.

[The prepared statement of Mr. Brown follows:]

# PRESENTATION TO THE CONGRESSIONAL SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS

February 29, 1984

## The Federal Role in Industrial Energy Conservation R&D

Presented by

Harry L. Brown

EG&G Idaho, Inc.
IDAHO NATIONAL ENGINEERING LABORATORY
DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE UNDER CONTRACT DE-AC07-76ID01570

# PRESENTATION TO THE CONGRESSIONAL SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS

## The Federal Role in Industrial Energy Conservation R&D

We have been asked for our views on the federal role in conducting research and development related to industrial energy conservation. Our comments are presented from the perspective of EG&G Idaho, Inc., prime contractor to the Department of Energy (DOE) at the Idaho National Engineering Laboratory (INEL). We at the INEL have participated in the Department of Energy's Office of Industrial Programs (OIP) energy conservation activities in both technical support and, to a lesser extent, R&D performance capacities for over seven years.

Our general remarks will note the industrial program accomplishments and how they have been achieved, and suggest how the federal role can be enhanced for future accomplishments. We will then discuss the thin strip steel casting project efforts which are an excellent example of this enhanced federal role.

### History

Since its inception, DOE's OIP has sponsored nearly 200 projects (mostly co-funded with industry) on research and development of new, high-risk, high-potential technologies for improved energy productivity. Of these projects, about 15% have been completed; the resulting process and hardware improvements are penetrating the industrial markets and are already saving over 21 trillion Btu annually over $100 million, at current prices.

### Rationale

Energy conservation is often characterized as the "cleanest, easiest, cheapest" way to ameliorate the consequences of uncertain energy supplies. Sustaining the rate of energy productivity increase for the nation will require the continuing development of new and innovative technologies. Development of these technologies will be somewhat more expensive than past efforts, but the benefits to the nation will be more than proportionately greater.

No developed technology can save energy in industry until it has been implemented by industry; only through the cooperation of industry can the particular technical, economic, and institutional barriers be understood by the government. OIP's present accomplishments are an example of a team effort, but industry acting alone is not likely to undertake R&D that has very high technical risk and requires very large expenditures or has only long-term payback potential. The industrial conservation program is therefore uniquely positioned to support research and development activities in which government and industry share the cost, risk, and benefits.

The cooperative approach to energy research has been successful. Close liaison with management and technical personnel in the private sector has been established and maintained by DOE-OIP. Workshops have been extremely valuable in ascertaining the technical needs of the larger energy consuming industries. Both unsolicited proposals and DOE solicitations based on identified needs have been the basis for successful programs. Action has been taken to secure the expertise of academia, and there has been appreciable involvement of small businesses. In fact, 75% of the R&D work has been performed by industry.

As OIP places increasing emphasis on higher-risk R&D initiatives, the technology being developed will be more responsive to national needs than to those of specific industries or firms. There is therefore a need for increased government/industry cooperation. One must then consider the value of an enhanced team approach in industrial energy conservation.

## Approach

This approach should continue to emphasize three vital elements of the federal role: (1) energy program initiation, (2) conduct of portions of

R&D project effort, and (3) technology transfer to the industrial public. It is crucial to all three elements that the responsive, cooperative relationship with industry be maintained.

Increasing reliance must be placed on government-initiated programs and projects for innovative longer-term, higher-risk, higher-cost, broad-application R&D. The needs and risk assessments which justify new programs will still require industry input, but, with less incentive for industry to initiate and conduct such work, DOE should supplement its historical "response" role with a greater degree of planning and initiation.

Because of the need for increased government/industry cooperation, it may be necessary to arrange for performance of R&D by organizations other than the private sector. Some can be handled by academia, but universities may be limited by either facilities or areas of excellence. DOE should enhance the existing cost-shared industry approach with government and government supported cooperative R&D.

Finally, a vigorous technology transfer effort is needed to enhance and supplement present methods. While trade associations and industry organizations will remain important to technology transfer, the more generic R&D will apply to wider, multi-industry audiences. Greater use should be made of scientific and engineering publications, conferences and seminars, and other media which reach the technical disciplines.

Through DOE, the federal government already has, in its National Laboratories, the facilities and expertise to put into effect these enhancements. These laboratories are a national resource and should be more fully utilized. In the industrial conservation program, use is being made of the Idaho National Engineering Laboratory, Argonne, and Oak Ridge to provide essential technical support. Such services include field management, evaluation of proposals, contract procurement and administration, technology assessment, and program planning. It may now be appropriate to expand the supporting role of the National Laboratories, in cooperation with industry, in formulation of government-initiated programs for innovative technologies, design and conduct of appropriate R&D activities for which the government should be responsible, and technology transfer to the scientific and engineering communities for industrial application.

We at INEL stand ready to play a greater role in industrial energy conservation R&D. The personnel, the expertise and the facilities are in place. We are enthusiastic about DOE-initiated R&D which can be performed with full disclosure for public benefit.

To recapitulate, the accomplishments of the industrial energy conservation program are outstanding and the methods are appropriate. We suggest an enhancement of these methods to specifically accommodate the longer-term, higher-risk, higher-cost, more generic R&D. Examples of such categories are waste heat recovery systems, separations technology, and high temperature materials. The last category includes continuous thin strip casting, to be discussed below. This enhancement will require an increase in the federal role, involving strong leadership in program initiation, project performance, and technology transfer. We are convinced that this can best be accomplished by supplementing the facilities and expertise of universities and the private sector with government resources already in place at the National Laboratories.

## Thin Strip Casting

As a part of this testimony, we have been asked to discuss the Thin Strip Steel Casting program managed by the Idaho Operations Office of DOE. This project serves as an example of the enhanced approach. It was government-initiated and, though in an early stage of development, has already involved the cooperative efforts of DOE, private industry, academia and National Laboratory personnel.

To provide a proper setting for this subject, we shall give a short background of continuous casting and note the possible energy savings.

Energy use in the USA for 1983 is estimated as 70 quads. Of this, 35% or 25 quads is for manufacturing.

In manufacturing, in the manufacturing sector metallurgical processes are large energy users, about 15% (~5 quads), because of the elevated-temperature operations. Three categories predominate: (1) iron and steel making, (2) iron casting, and (3) forging.

## History of Continuous Casting

The first industrial applications of continuous casting occurred within the past 40 years. This technology produces sections of 4-inch or greater thickness which still require hot reduction, but less so than ingots. Continuous casting was adopted sooner and to a greater extent in Europe and Japan than in the USA.

More recently, very thin materials (less than 0.010 inch) have been produced by continuous casting techniques to meet special requirements. The production techniques, however, may lend themselves to somewhat thicker sections for more common applications.

The thicknesses of concern for steel sheet and strip, typically 0.030 to 0.187 (1/32 to 3/16) inch, are well outside the capabilities of the two existing continuous casting technologies. Our present concern is to bridge this gap. The potential energy and economic savings are large, and success may help greatly in revitalizing the American steel industry to compete with foreign sources.

## Industry Status

Thirty million tons of relatively thin sheet and strip are currently produced annually in this country. The majority of this material goes into cars and appliances. Substantial amounts of energy are needed to make these products from heavy sections. Estimates of energy savings from use of continuous thin strip casting range from 5 to 10 million Btu per ton, depending on the base process compared. Assuming \$5/MMBtu, this represents at least a \$750 million saving per year.

The technical and patent literature reveals the interest in this new technology which can save both energy and capital costs associated with process equipment and reheat requirements. A number of patents for making commercial steel strip by continuous casting were granted within the past 15 years, but have not been developed.

Other patents relate to rapid solidification technology for producing much thinner sections than current steelmaking practice. This technology covers several versions of the basic equipment, now used commercially to cast special materials as well as lower-melting metals such as alloys of copper and aluminum. However, none of these applications approaches the potential volume and energy savings of thin steel strip and sheet.

A more detailed appraisal of current continuous casting technology has been made by General Electric Company, under a recent Department of Energy contract. This information is the basis of another presentation today, by Dr. Jay Desai.

## Background of DOE Interest in Continuous Casting

The Department of Energy has for some years supported work in both energy conservation and energy development. Two separate objectives govern these programs. First, appreciable energy savings must be possible. Second, economic benefits must permit a satisfactorily short payback period and thus encourage adoption of the technology. The thin strip program fits this description well.

## DOE Efforts To Date

In July 1982, DOE issued a Notice of Program Interest (NOPI) requesting proposals for concept development and feasibility studies in the area of thin strip casting. The key paragraph of the NOPI is included as Attachment I to this presentation.

Seven proposals were received; four were selected for contract negotiations. Contract agreements were negotiated, representing industry, non-profit research institutions, and academia. In alphabetical order they are:

| | |
|---|---|
| Battelle Columbus Laboratories<br>Columbus, Ohio<br>$73,000 | Develop mathematical simulation model. |
| General Electric Company<br>Schenectady, New York<br>$98,000 | Evaluation of the current thin-strip production and use picture and of current continuous casting technology to permit process selection. |
| Massachusetts Institute of Technology (MIT)<br>Materials Processing Center<br>Cambridge, Massachusetts<br>$80,000 | Experimental and analytical studies to assess the single-wheel casting process. |
| Westinghouse Electric Corporation<br>(with U.S. Steel Research Laboratory<br>as subcontractor)<br>Pittsburgh, Pennsylvania<br>$80,000 | Experimental and analytical evaluation of planar flow casting. |

Three of the four proposals recommended or referred to a three-phase program involving:

- Concept development and feasibility studies (Phase I)
- Concept selection and experimental characterization (Phase II)
- Pilot-plant-scale process development (Phase III).

Rough estimates for the Phase II research ranged from $320,000 to $2,500,000. No cost estimates were made for the Phase III pilot-scale work, and the MIT proposal was limited to Phases I and II.

All four contractors have recently completed their Phase I investigations. Brief synopses of these projects, as well as general conclusions drawn from them, are included as Attachment II to this statement.

The four studies do not identify a clear-cut choice of one process to pursue. Rather, the two promising options (single- and double-roller/belt) described in Attachment II require characterization on a somewhat expanded laboratory scale, to define the advantages and problems of each option. In this context, the details of the necessary follow-on work become clearer. They include experimental development followed by pilot plant design and operation.

## Additional DOE Work

An additional DOE effort dates from June 1982, when an innovative approach to continuous thin strip casting was conceived by DOE-OIP personnel. INEL scoped and analyzed the thermal aspects of the concept to determine its practicability for possible patent action. The INEL work provided the necessary data and a patent application covering the DOE conceived double-clad thin strip casting process was filed by DOE in November 1983. A summary of the INEL scoping and modeling effort appears in Attachment III to this presentation.

Although its energy-saving potential is slightly less than other thin-strip concepts, the double-clad thin-strip process has at least two noteworthy advantages. First, it appears to require less technological development for near-term application. The required surface quality and product structure are basic to the concept. Second, it seems well-suited for specialty products of high market value. Two examples are highly alloyed materials and combinations of dissimilar metals.

## Follow-On Work

As stated earlier, three of the four award-winning proposals under the 1982 NOPI addressed technology development and ultimate demonstration on a pilot plant scale. During the Phase I studies, the steel industry's increasing interest in thin strip casting became apparent. A news release announced a joint Battelle Columbus Laboratories/National Steel Company effort concurrent with Battelle's Phase I work. (The DOE-Idaho Operations Office has received numerous inquiries concerning all of the Phase I program activities.)

Further interest in thin strip casting became obvious with the 1984 appropriations legislation which resulted in the Thin Strip Casting Pilot Plant Project (PPP) and reaffirming the continuation of related work initiated under the four feasibility study contracts (referred to as "Phase II and following") pursuant to the 1982 NOPI. In compliance with the intent of this legislation, a Solicitation for Cooperative Agreement Proposals (SCAP) No. DE-SC07-84ID12500 has been issued by DOE. The complementary relationship between the PPP and the Phase II and following efforts is being studied by DOE to minimize duplication of work and obtain maximum beneficial input to the overall technology development. Selection of the winning PPP proposal is scheduled for no later than May 15, 1984. Proposals for Phase II and following work will be considered after that date.

The Pilot Plant Project is seen as a five-step effort:

1. Feasibility studies

2. Process characterization, selection, and conceptual design

3. Preliminary plant design

4. Pilot plant final design and construction

5. Pilot plant operation.

Program entry at any of the first three steps is permitted if adequate information showing completion of the omitted steps is presented to DOE.

The referenced SCAP calls for repayment of federal funding from the profits of subsequent technology use (and licensing). This provision tacitly acknowledges that the industry may presently require financial support in undertaking major development efforts for new technology but emphasizes that the work, to merit support, must have a reasonable expectation of profitable results; therefore, the federal support should ultimately be repaid. It is implicit that federal support may not cover the entire cost of the work. Past proposals from both industry and academic institutions have frequently included provisions for use of facilities and equipment at reduced rates, and certain overhead expenses have also been partially absorbed.

From the industrial and academic interest already exhibited, we feel that the timing is right for increased development activity in continuous strip casting. Further development of thin strip casting is expected from the responses to the current solicitation.

## Further Comments on the Present Federal Role in Energy Conservation

The cooperative approach to technology development has tangible benefits:

- The work is done sooner than if left completely to industry.
- Cross-fertilization of ideas occurs from reviewing and monitoring personnel.
- The work may be more closely tailored to national needs.
- Economic benefits can be more widespread as a result of technology transfer.

With respect to the thin-strip casting initiative, the implications of the federal role are strong--our domestic steel industry must be revitalized.

- Foreign competition can be met only with an equally advanced domestic capability.
- For our industry to merely pace foreign competition is not effective; a major step forward is needed to give us a technical lead as well.

Our metal industries are handicapped economically because they are not sufficiently competitive with foreign suppliers. Economic problems preclude development of this technology without assistance. The federally funded thin-strip initiative provides the needed assistance on a sound technical and economic basis. The desired role of National Laboratories in helping develop the necessary initiatives has already been described.

In summary, the federal role, as we see it, involves a broader view and increased effort to push high-risk programs. Past involvement indicates to us that a cooperative effort involving DOE-OIP, industry, and academia, with active assistance on the Federal level by the National Laboratories, is the most effective route.

## ATTACHMENT I

### Phase I Program

Recognizing the potential energy savings to be gained from the successful development of a direct, thin-strip casting process, DOE issued a Notice of Program Interest (NOPI) in late July 1982. The NOPI stated that:

> "DOE IS INTERESTED IN RECEIVING PROPOSALS FOR TECHNOLOGY DEVELOPMENT OF ENERGY EFFICIENT PROCESSES TO PRODUCE THIN STRIP STEEL PRODUCTS. THE CAST THICKNESS RANGE OF PRIMARY INTEREST IS 0.030 INCH TO 0.050 INCH. THE PROPOSED PROJECTS SHOULD HAVE AT LEAST TWO PHASES, WITH SEPARATE TASK DESCRIPTIONS AND BUDGETS FOR EACH PHASE. THE FIRST PHASE SHOULD BE DIRECTED TO PRELIMINARY CONCEPT DEVELOPMENT AND A FEASIBILITY STUDY. ACTUAL EXPERIMENTAL OR LABORATORY WORK IS NOT A REQUIREMENT OF THIS PHASE. HOWEVER, THE PROPOSALS SHOULD CONTAIN PROVISIONS FOR FORECASTING THE PERFORMANCE OF A STRIP STEEL CASTING SYSTEM AND COMMENT ON THE RELATIVE IMPORTANCE OF VARIOUS PARAMETERS. THE SECOND PHASE OF THE PROPOSAL SHOULD OUTLINE THE FUTURE PROGRAM, INCLUDING MEANINGFUL EXPERIMENTAL WORK."

## ATTACHMENT II

## Phase I Program Synopses

### Battelle Columbus Laboratories (BCL)

BCL developed a mathematical simulation model to study two basic thin strip casting processes, one using a single casting wheel and the second using two opposing casting wheels. The model was used to perform analyses of the sensitivity on the product thickness of the two processes to variations in the casting parameters such as wheel speed, orifice size, temperature of melt, distance between orifice and wheel, etc.

Summarizing the results, the analyses show that the two processes respond differently to variations in operating conditions. The single roller (or wheel) process strip integrity and has low sensitivity to changes in operating parameters whereas the strip thickness has high sensitivity to changes in operating parameters. The double roller process strip integrity has high sensitivity to changes in operating parameters, whereas the strip thickness has low sensitivity to these same changes. It was concluded that the double roller process requires much more rigorous process control than the single roller. The single roller process was therefore chosen by BCL for more detailed investigation as a potential commercial process for the production of steel strip in thicknesses up to 0.05 inch.

### General Electric

General Electric Co. conducted a study of the state-of-the-art of continuous casting processes having the necessary technological potential for meeting industry steel strip production requirements. Candidate processes were selected and data on each process were obtained from the literature and from industry contacts. A detailed analysis and comparison was performed using a quantitative decision analysis technique in which the various process characteristics were compared against sets of MUST (go/no-go) and WANT (desirable) criteria. The criteria were developed using the combined expertise and information bases of GE, members of the steel industry, equipment manufacturers, consultants, and DOE and its national laboratory personnel.

The results of the analyses showed that several processes had the desired characteristics for further development. However, some of the processes have near-term potential for yielding a product which would serve particular market niches, and two process concepts (twin belt and "single" roller casting) emerged as having particularly good potential for scale-up for major market use. The twin belt process is considered a low-risk, low-return approach and the single roller (wheel) is considered a higher risk, higher-return approach. The risk is in terms of development cost and the probability of achieving technical and economic success. The return is in terms of energy savings and reduced capital and production costs. The GE report should serve as the most comprehensive and up-to-date source of reliable information that is currently available on the subject of thin strip casting.

## Massachusetts Institute of Technology

MIT performed experimental and analytical studies to assess the technical potential of a single wheel (or roller) casting process to produce steel strip in the initial thickness range of 0.03 to 0.05 inch which would subsequently be reduced to smaller thicknesses to meet market requirements. The experimental techniques included casting of nonferrous and stainless steel materials on a small, laboratory-size casting wheel using both vacuum and inert-gas environments. A steady magnetic field was applied to some of the trial casts to assess its effect on the product quality and its ability to influence the liquid metal flow pattern. In addition, MIT reported on two other approaches to continuous strip casting that the authors feel show promise for scaling up to industrial size; semi-solid casting (Rheocasting) and spray casting. Neither of these processes was extensively evaluated during the project.

MIT achieved an experimental cast strip of 304 stainless steel of approximately 0.020 inch thick and 0.5 inch wide with a good quality bottom

ATTACHMENT II

surface (in contact with casting wheel) but poor quality top surface (free to atmosphere--inert gas, vacuum or air). They determined that a vacuum entrapment and prevents uniform metal-to-wheel contact. Application of a steady DC magnetic field to the molten puddle zone refines the microstructure and results in a thicker sheet than is otherwise obtained.

MIT's final conclusions are that there is no published evidence of an existing process for casting 72-in-wide sheet in the 0.010 to 0.187 inch thickness range that can overcome the "curx problems" of achieving adequate surface finish and freedom from cracking. They also recommend that prior to selecting a process concept for pilot plant development that it be clearly demonstrated (in laboratory tests) that the crux problems of surface finish and cracking have been overcome.

## Westinghouse Electric and U.S. Steel Corprs.

Westinghouse performed analytical and experimental evaluations of a "planar flow casting" process which is one of several variations of the single wheel (or roller) thin strip casting process. A mathematical model was developed to analyze the basic parameters for planar flow casting of ferrous alloys in relatively thick 0.050 inch) sheets. The modeling results were compared with experimental runs on a small, solid casting wheel with good agreement. Electromagnetic field control of the molten metal puddle was also analytically evaluated and it was concluded that such an approach was feasible but would add additional cost and complexity to the process.

U.S. Steel Corporation, under subcontract to Westinghouse, performed a detailed energy impact analysis to estimate the energy conservation potential of thin strip casting when compared to slab casting and continuous strand casting routes for production of steel sheet and strip. The results range between 5 and 10 million Btu/ton of product savings potential depending on which of several processing steps can be successfully bypassed by the new technology.

## ATTACHMENT II

Westinghouse concluded that the planar flow casting concept has the technical potential to be scaled up to a commercial process for the production of steel sheet and strip. They recommend that a second phase research program is needed to: (1) verify the assumptions used in, and the predictions obtained from Phase I; (2) determine practical process parameters; and (3) demonstrate physical and metallurgical quality of the product. Results of these Phase II investigations would then be used to plan a pilot scale facility.

### General Conclusions from Phase I Results

1. a. There is a substantial energy conservation potential inherent in direct steel strip casting processes, with estimates ranging from 5 to 10 million Btu per ton of product. The total annual estimated U.S. energy savings range from 0.15 quad (quadrillion Btu) based on 5 million Btu per ton savings and 30 million tons production to 0.5 quad based on 10 million Btu per ton savings and 50 million tons annual production.

   b. Capital and operating costs for direct strip casting processes are expected to be significantly lower than for current practice.

2. There is no known and proven continuous casting process presently capable of casting steel sheet and strip at near final product thickness that is capable of meeting existing product quality specifications.

3. Two generic continuous casting process concepts have emerged as the leading candidates for additional research and development: (a) the single roller (wheel) as the high risk, high return approach, and (b) the twin belt casting process as the lower risk, lower return approach. Risk is in terms of the probability of achieving technical development success, and return is in terms of energy savings and reductions in capital and operating costs.

4. Additional development of candidate processes is necessary prior to selecting a single process for pilot plant development.

5. The main thrust of the additional development should be to determine if the control of process parameters necessary to produce the desired product quality can be achieved within acceptable limits of cost and process reliability.

6. Assuming success in step number 5 above we should proceed with pilot plant development of the successful concept.

## ATTACHMENT III

# THERMAL ANALYSIS OF A CONCEPT FOR THIN STRIP STEEL CASTING

EG&G Idaho, Inc.

A novel concept for production of thin metal sheet and strip by direct continuous casting has been investigated by the U.S. Department of Energy and a U.S. patent applied for. The expected product thickness falls between the lower limits of continuous casting as now practiced and the upper limits of rapid solidification technology (RST). Surface quality problems associated with some current RST products are minimized by the technique. Product recycling to provide the strip material is approximately 20%.

Conventional strip/sheet production from molten steel proceeds from either an ingot or a section of a continuous-cast billet, with successive hot-working reductions to a thickness suitable for cold reduction and finishing. The twin-strip approach promises to eliminate essentially all reheat requirements by casting a near-net thickness product. The energy requirements per ton of finished product are thus reduced by as much as $5 \times 10^6$ Btu compared with current continuous casting practice. No economic analysis of the twin-strip casting concept was performed during this study.

The concept involves casting molten steel into a mold partially composed of two parallel metallic strips of suitable composition. Edge containment for the molten metal is also provided. The hot metal bonds to the strips, which then become an integral part of the product. The casting operation and the initial product cooling take place in an inert gas environment, to minimize oxidation.

Two equipment configurations were analyzed for thermal behavior. In the first, force-cooled twin rollers maintain product thickness and provide a primary heat sink; product support and supplemental cooling is provided by a secondary roller and a series of idlers. The product is cooled only enough to permit handling.

The second configuration uses twin belts for heat transfer and product support. Large, force-cooled drive rollers position the twin belts; belt support and partial cooling along the casting span is achieved by idlers or rigid support slabs.

A detailed computer model of thermal behavior shows both configurations are feasible from a thermal standpoint. The twin-belt configuration has both thermal and mechanical advantages over the wheel casting approach. Mechanical parameters were assumed as necessary for the modeling process.

Mr. FUQUA. Thank you very much, Mr. Brown.

Dr. Desai?

## STATEMENT OF DR. JAY D. DESAI, PROGRAM MANAGER, CORPORATE RESEARCH AND DEVELOPMENT, GENERAL ELECTRIC CO.

Dr. DESAI. Thank you, Mr. Chairman.

Mr. Chairman and members of the committee, I wish to have my written testimony be made part of the record.

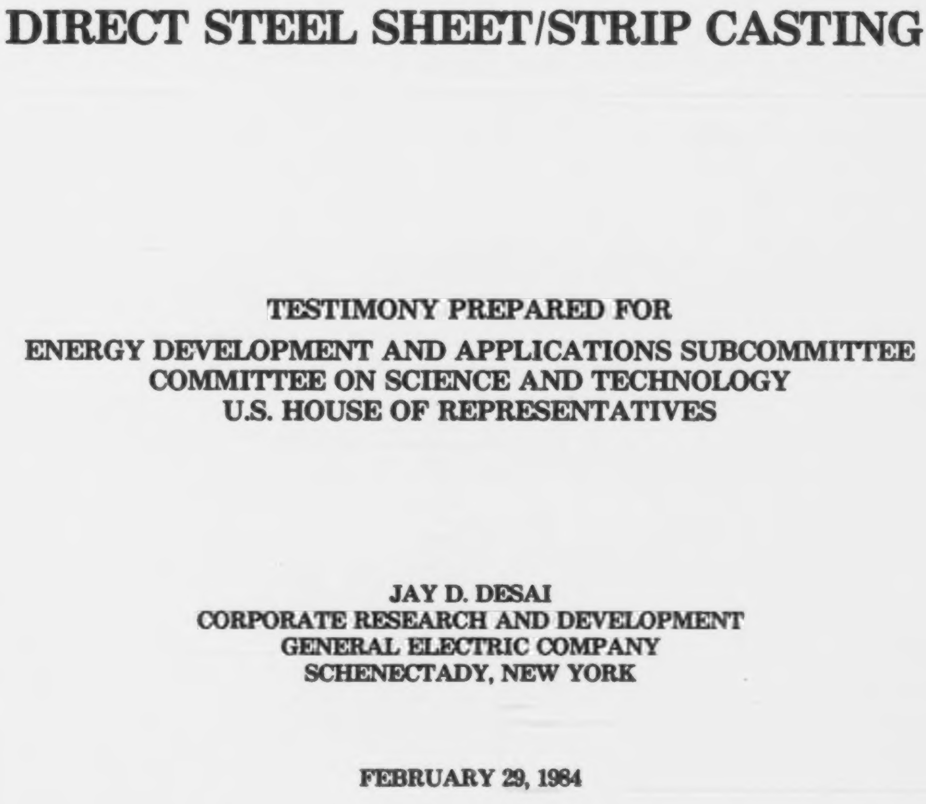
Mr. FUQUA. Without objection.

Dr. DESAI. I am Jay Desai, and I am from General Electric Co., Corporate Research and Development Center.

I would like to thank you for this opportunity to testify before the House Science and Technology Committee.

If I may use the Vu-Graphs—(which are included in the presentation material)—to my right, I will proceed. Mr. Chairman, you have two different handouts with the same cover sheet, but I will be going through Vu-Graphs.

[Slide 1 shown.]



# DIRECT STEEL SHEET/STRIP CASTING

TESTIMONY PREPARED FOR

ENERGY DEVELOPMENT AND APPLICATIONS SUBCOMMITTEE
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

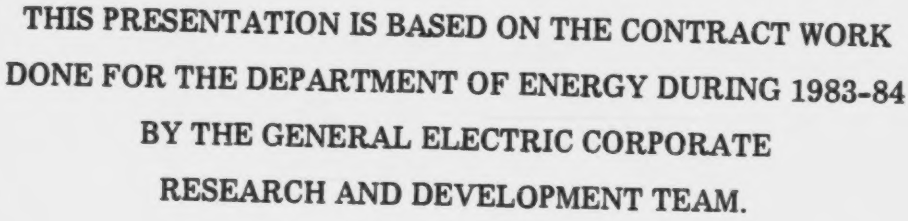
JAY D. DESAI
CORPORATE RESEARCH AND DEVELOPMENT
GENERAL ELECTRIC COMPANY
SCHENECTADY, NEW YORK

FEBRUARY 29, 1984

SLIDE 1

The purpose of this testimony is to discuss the technical and economic aspects of the direct steel sheet-casting processes which can have a significant potential impact on the iron and steel industries.

[Slide 2 shown.]



THIS PRESENTATION IS BASED ON THE CONTRACT WORK
DONE FOR THE DEPARTMENT OF ENERGY DURING 1983-84
BY THE GENERAL ELECTRIC CORPORATE
RESEARCH AND DEVELOPMENT TEAM.

SLIDE 2

This presentation is based on the work done by the General Electric Corporate Research and Development Center team under contract to DOE during the 1983-1984 period.

[Slide 3 shown.]

## DIRECT STEEL SHEET CASTING

- MOTIVATION
- CURRENT SHEET MAKING PROCESSES
- COMPETITIVE POSITION
- NEW SHEET MAKING PROCESSES
- PROCESS EVALUATION
- JAPANESE DEVELOPMENTS
- RECOMMENDATIONS

SLIDE 3

I would like to discuss the following topics: first, I would like to discuss the motivation for the study; next, the current sheetmaking processes, followed by the competitive position the United States is in; then the new sheetmaking processes and their evaluation as carried out by General Electric Co., followed by some observations on the Japanese development; and I would like to end with a set of recommendations.

[Slide 4 shown.]

## MOTIVATION

- CONSERVING ENERGY
  - IRON AND STEEL MELTING ∽ 4 PERCENT
  - ROLLING ∽ 1 PERCENT
- SERVING LARGE SHEET STEEL MARKET
  - 50% OF U.S. STEEL PRODUCTION
- MAKING U.S. STEEL INDUSTRY MORE COMPETITIVE

Slide 4

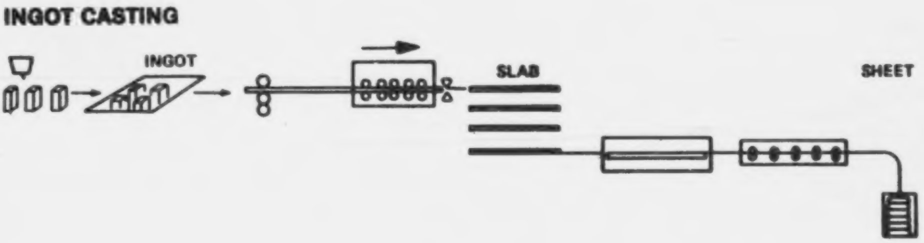
There are three major reasons for motivations for the study. The first one is conserving energy. The domestic iron and steel industry uses approximately 5 percent of the total U.S. energy consumption, which can be broken into 4 percent for iron and steel melting and 1 percent for rolling and other processes. It is the prospect of eliminating part of this 1 percent of U.S. energy consumption that has motivated this study.

The second reason is that of serving a large sheet steel market. The fact that the sheet steel market accounts for approximately 50 percent of the total U.S. steel production makes the potential economic and technical gains from this new direct casting technology even more significant.

Finally, and probably the most important motivation, is making the U.S. steel industry more competitive. In the 1950's, the U.S. steel industry was the largest and most efficient in the world. Today that place is taken by Japan and European countries.

Rapid development and commercialization of new direct sheet casting technology can make the U.S. steel industry more competitive again. We will discuss this point again a little bit later on.

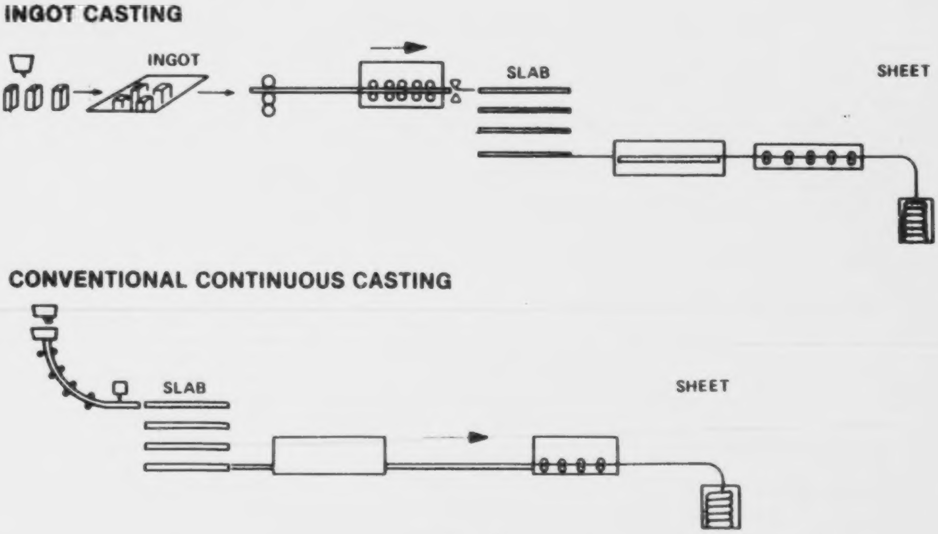
[Slide 5 shown.]



SLIDE 5

Let us look at what the current sheet-making processes are. The ingot casting process, shown here, which is now obsolete, but still the predominant one in the United States, goes through many steps by casting large ingots which are rolled to approximately 10-inch-thick slabs, which are further rolled into ⅒ inch-thick sheets, the sheet sizes typically used in car bodies and appliances. Iron and steel making precedes the ingot breakdown and rolling steps shown in this figure.

[Slide 6 shown.]


INGOT CASTING

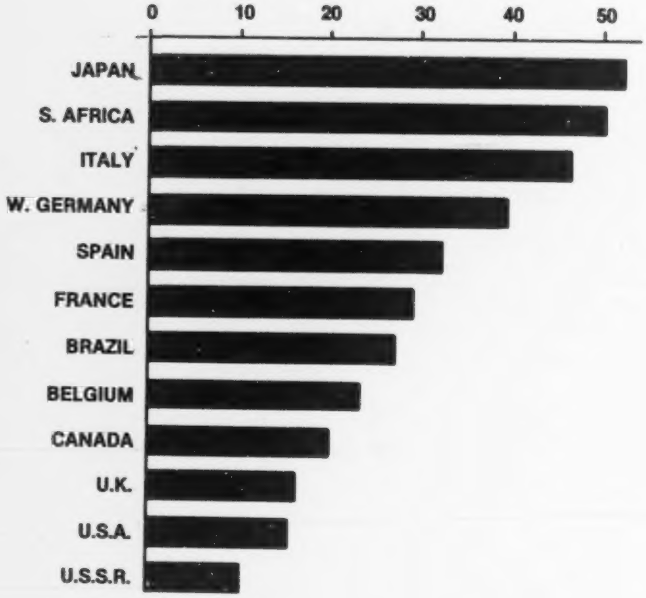
CONVENTIONAL CONTINUOUS CASTING

Slide 6

With significant developments in the 1950's and 1960's, the process of conventional continuous casting came about, which is shown as the lower part of this figure. This shows that approximately a 10-inch-thick slab is produced directly from the molten metal, thus eliminating the ingot breakdown steps shown in red. This provides significant gain in energy, manufacturing cost, and capital equipment cost with a simultaneous improvement in product quality.

[Slide 7 shown.]

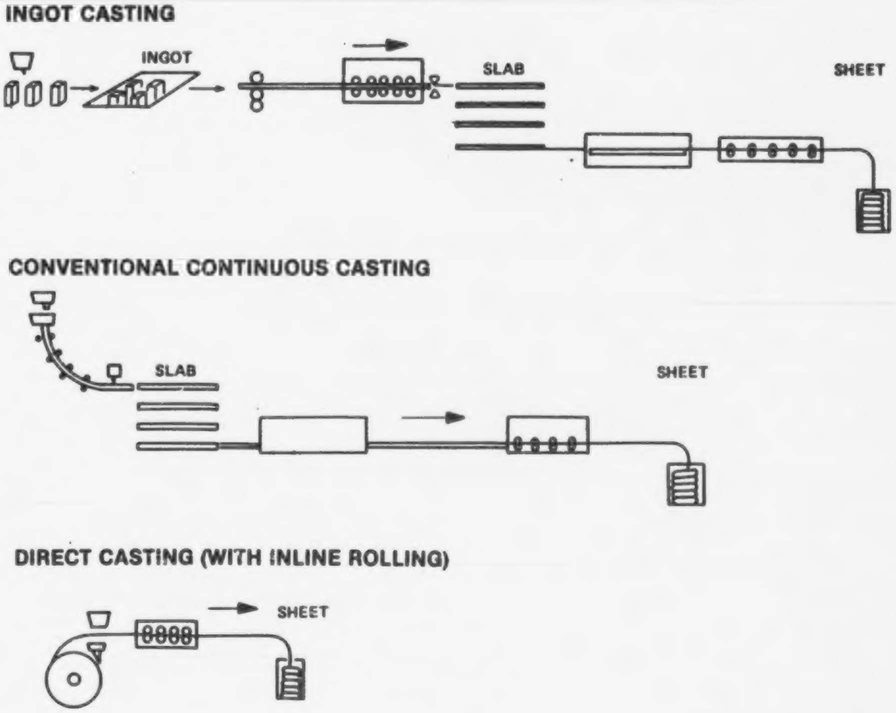
**PERCENTAGE CONTINUOUSLY CAST, 1980**



Slide 7

As a result, by 1980, many countries in the world implemented this technology as shown in the next Vu-Graph. Japan is a clear leader. There are at least 10 countries ahead of the United States. In 1983, Japan has taken even a bigger lead over the United States.

[Slide 8 shown.]



INGOT CASTING

CONVENTIONAL CONTINUOUS CASTING

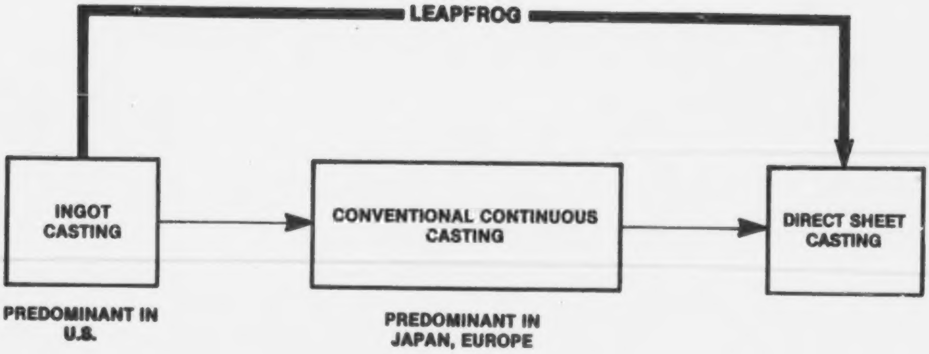
DIRECT CASTING (WITH INLINE ROLLING)

SLIDE 8

Now, in the 1980's, another significant development is taking place, that of direct sheet casting close to final dimensions, as shown in the last figure in this Vu-Graph. Savings in energy, manufacturing cost, and capital equipment cost, by eliminating a number of rolling steps as compared to conventional continuous casting, is very clear.

In this process, both ingot breakdown and most of the rolling steps have been eliminated, as shown in the red parts of the figure. This is the type of process we are concerned about. So what is the importance of this new technology to the United States?

[Slide 9 shown.]



LEAPFROG

INGOT CASTING

CONVENTIONAL CONTINUOUS CASTING

DIRECT SHEET CASTING

PREDOMINANT IN U.S.

PREDOMINANT IN JAPAN, EUROPE

SLIDE 9

The United States, with a predominant ingot casting process, may be able to "leapfrog" foreign competition by implementing the new direct casting technology as shown here. Japan and European countries, with relatively new conventional continuous casting installations, may not be able to readily convert to the new technology because of economic tradeoffs.

This is precisely what the current leading steel-producing countries did to the United States in the 1960 to 1980 period. We will come back to this point in a minute.

Now let us take a look at what these new processes are.

[Slide 10 shown.]

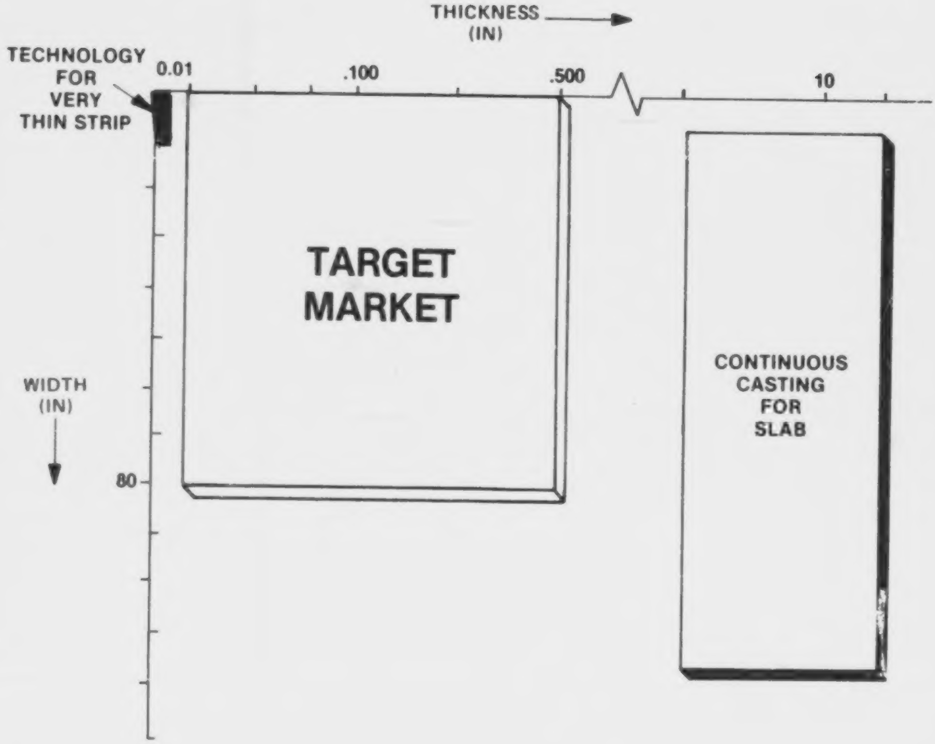
## CANDIDATE PROCESSES

- CONVENTIONAL CONTINUOUS CASTING WITH STATIONARY MOLD
- CONTINUOUS CASTING WITH MOVING MOLD
  - TWIN BELT
  - WHEEL—BELT
  - INSIDE-THE-RING
  - TWIN ROLLER
- ROLLER CASTING PROCESSES
  - SINGLE ROLLER AND ITS VARIATIONS
    - MELT SPINNING
    - PLANAR FLOW CASTING
    - MELT DRAG
  - TWIN ROLLER
- SPRAY ROLLING

Slide 10

There are many different processes identified here. We will not discuss the details this morning. However, these processes can be grouped into two broad categories: Continuous casting processes, which can make wide, thick slabs; and roller casting processes, which can currently produce very thin and narrow strips.

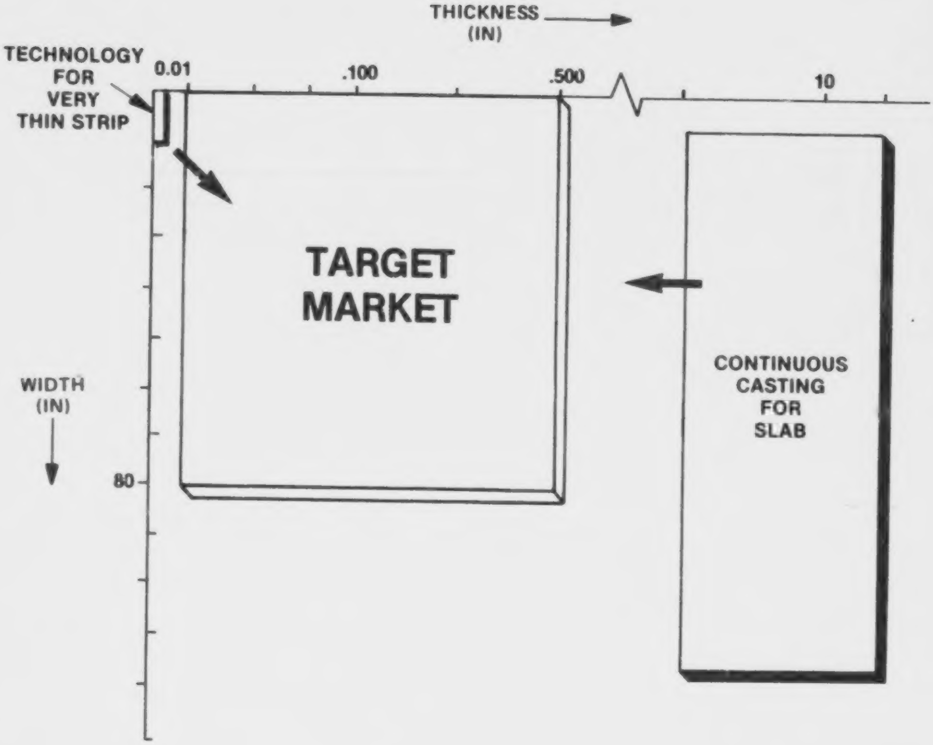
[Slide 11 shown.]


THICKNESS (IN)
TECHNOLOGY FOR VERY THIN STRIP
0.01
.100
.500
10
TARGET MARKET
CONTINUOUS CASTING FOR SLAB
WIDTH (IN)
80

Slide 11

The current capabilities of these two broad process categories are shown in yellow in two different blocks, to the left and right, in this figure, and they are different from the thickness and the width of the sheet product for the target market, which is shown in red.

[Slide 12 shown.]

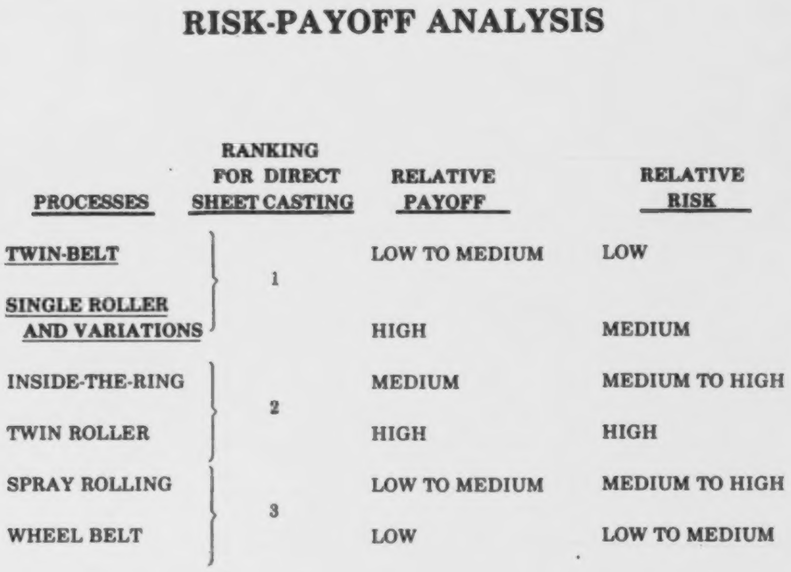

THICKNESS (IN)
TECHNOLOGY FOR VERY THIN STRIP
0.01
.100
.500
10
TARGET MARKET
WIDTH (IN)
80
CONTINUOUS CASTING FOR SLAB

SLIDE 12

It is clear that the new technologies require development effort in either scaling up both thickness and width, as for the technology for very thin strip casting shown on the left, or by scaling down in thickness with continuous casting of slabs, shown on the right. This is shown by black arrows in this particular figure.

GE Corporate Research and Development Center has carried out a comprehensive evaluation of these processes. The risk payoff analysis is shown in the next chart.

[Slide 13 shown.]



## RISK-PAYOFF ANALYSIS

| PROCESSES | RANKING FOR DIRECT SHEET CASTING | RELATIVE PAYOFF | RELATIVE RISK |
|---|---|---|---|
| TWIN-BELT | 1 | LOW TO MEDIUM | LOW |
| SINGLE ROLLER AND VARIATIONS | | HIGH | MEDIUM |
| INSIDE-THE-RING | 2 | MEDIUM | MEDIUM TO HIGH |
| TWIN ROLLER | | HIGH | HIGH |
| SPRAY ROLLING | 3 | LOW TO MEDIUM | MEDIUM TO HIGH |
| WHEEL BELT | | LOW | LOW TO MEDIUM |

SLIDE 13

The payoffs are in terms of savings in energy, manufacturing cost, and capital equipment cost. The risk is associated with the technical feasibility of the process, scaleup risk, and operational and control problems.

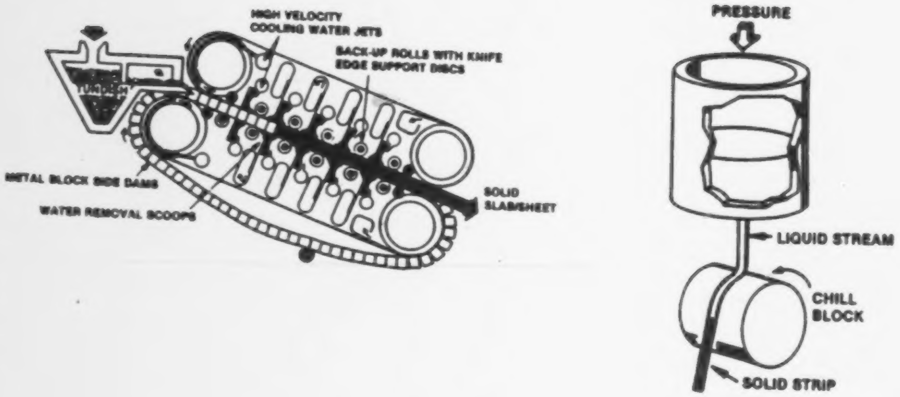
Two processes stand out: The twin belt process, with low to medium payoff and low risk; and single-roller process, with high payoff and medium risk. Other processes are rated lower in this type of risk payoff analysis.

In the United States, the two recommended processes are also at more advanced stages of development as compared to the other processes.

The two recommended processes are shown in the next figure.

[Slide 14 shown.]

**TWIN-BELT** **SINGLE ROLLER**


TUNDISH
HIGH VELOCITY COOLING WATER JETS
BACK-UP ROLLS WITH KNIFE EDGE SUPPORT DISCS
METAL BLOCK SIDE DAMS
WATER REMOVAL SCOOPS
SOLID SLAB/SHEET
PRESSURE
LIQUID STREAM
CHILL BLOCK
SOLID STRIP

Slide 14

The twin-belt process, where the molten steel is cast between two moving belts, and the single-roller process, where the molten steel is cast on a roller moving at a high speed, as shown on the right.

The twin-belt process can make a thicker product than the single-roller process. Thus, the two processes can satisfy two different market needs—thin as well as thick sheets.

## JAPANESE DEVELOPMENTS

- SEVERAL PILOT PLANTS
- DIVERSIFIED APPROACH
  - AT LEAST THREE PROCESSES
  - MANY PRODUCT FORMS
    THIN AND THICK SHEET, BILLET
- COOPERATIVE ENTERPRISE
- COMMERCIAL PRODUCTION IN 3-6 YEARS

Slide 15

Let us take a look at what the current steel industry leader, Japan, is doing. The key observations made during my recent visit to Japan are shown next.

Japan already has several pilot plants. Japan has taken a very diversified approach and is looking at, at least three different processes and many different product forms like thin- and thick-sheet as well as billet.

The third important point is the cooperative nature of the enterprise involving steel companies, equipment manufacturers, and universities. In any event, it appears that we may see some commercial production in Japan in the next 3 to 6 years.

Although new plants may implement new technologies, because of the economic tradeoffs, the rate of conversion may be somewhat slow. So what are the opportunities for the U.S. steel industry?

[Slide 16 shown.]

## OPPORTUNITY

- LEAPFROG FOREIGN COMPETITION
- SIGNIFICANT COST REDUCTION

| | |
|---|---|
| ENERGY | $20 — 60/TON |
| CAPITAL INVESTMENT | 40 — 70 PERCENT |
| MANUFACTURING<br>AUTOMATION<br>PRODUCTIVITY GAINS | 40 — 50 PERCENT |

- POSSIBLY IMPROVED PRODUCT QUALITY

SLIDE 16

As explained earlier, the United States may be able to leapfrog some foreign competition by implementing the new direct sheet-casting technology.

Second, there are significant cost reduction potentials. The energy savings can be in the range of $20 to $60 per ton; savings in capital cost, approximately 40 to 70 percent; and savings in manufacturing costs, including those resulting from automation and productivity gains, may be as high as 40 to 50 percent. These savings are as compared to ingot casting, which is still the predominant process in the United States.

Finally, there is a possibility of improved product quality as was obtained when changing from ingot casting technology to today's conventional continuous casting process.

[Slide 17 shown.]

## RECOMMENDATIONS

- **DEVELOP TWO DIRECT CASTING TECHNOLOGIES**

| | |
|---|---|
| **SINGLE ROLLER** | **TWIN BELT** |
| **THIN SHEET** | **THICK SHEET** |

- **SOLVE TECHNICAL PROBLEMS BEFORE PILOT STAGE**
- **CONSIDER OTHER DIRECT CASTING TECHNOLOGIES e.g. BILLET**
- **ESTABLISH COOPERATIVE EFFORT**

**STEEL INDUSTRY, EQUIPMENT MANUFACTURER, UNIVERSITY**

## COMPETITIVE RISK DEMANDS ACTION

SLIDE 17

Based on this review, our recommendations are shown in the last Vu-Graph. We should develop two direct sheet casting technologies: the twin-belt process for thick sheet and the single-roller process for thin sheet, thus approaching the target market thickness requirements from two opposite sides, as shown in this figure, which was discussed previously (slides 11, 12).

This will allow us to cover the entire market for sheet steel. Second, the technical problems should be solved before the pilot stage. This may require R&D effort over a period of 1 to 2 years and an expenditure of $2 million to $3 million.

Third, consider other direct casting technologies; for example, billet, as is being done in Japan.

Finally, establish cooperative efforts with steel companies, equipment manufacturers, and possibly university participation. Above all, the competitive position of the U.S. steel industry demands that action be taken.

Thank you.

[The prepared statement of Dr. Desai follows:]

# DIRECT STEEL SHEET/STRIP CASTING

TESTIMONY PREPARED FOR
ENERGY DEVELOPMENT AND APPLICATIONS SUBCOMMITTEE
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

JAY D. DESAI
CORPORATE RESEARCH AND DEVELOPMENT
GENERAL ELECTRIC COMPANY
SCHENECTADY, NEW YORK

FEBRUARY 29, 1984

THIS PRESENTATION IS BASED ON THE CONTRACT WORK DONE FOR THE DEPARTMENT OF ENERGY DURING 1983-84 BY THE GENERAL ELECTRIC CORPORATE RESEARCH AND DEVELOPMENT TEAM.

## BIOGRAPHICAL SKETCH — JAY D. DESAI

### EDUCATION

| | |
|---|---|
| B.S. | Metallurgical and Mechanical Engineering<br>Indian Institute of Technology, Bombay, 1971 |
| M.S. | Metallurgy, Materials Science and Industrial Engineering<br>University of Minnesota, 1973 |
| MBA | University of Minnesota, 1976 |
| PhD | Materials Engineering, Rensselaer Polytechnic Institute, 1981 |

### EXPERIENCE

Prior to joining General Electric in 1977, Dr. Desai worked with Hitchcock Industries, Minneapolis, Minnesota. His first assignment was as Quality Control Engineer/Metallurgist encompassing all the foundry operations for manufacturing aluminum, magnesium and copper base castings. Subsequently as Manager of Special Projects, he interacted with the manufacturing, development, engineering, quality control, accounting-finance, sales-marketing and the purchasing functions. He has also worked with several other manufacturing companies.

He has been with GE Corporate Research and Development Center for 7 years. His current assignment includes project/program management and financial responsibilities. He has worked on many government, defense and company contracts; training courses, and special publications in materials, processes and related areas, and he has developed/invented materials and processes for all three Department of Defense agencies. He has directed and taught courses in electrical contacts, casting technology, engineering fracture mechanics, materials and processes, and manufacturing engineering which includes computer aided design and manufacturing, and robotics.

He is a member of the American Society for Metals, American Society for Testing Materials, and the American Foundrymens Society. He has published many invited and other research and review papers, and he holds four patents.

He was Program Manager for this study.

## PURPOSE OF TESTIMONY

The purpose of this testimony is to discuss the technical and economic aspects of direct steel sheet/ strip casting.

## INTRODUCTION

The production of steel sheet is a major U.S. business accounting for nearly half of the total U.S. steel production. The rolling of sheet and strip from heavy steel slabs utilizes significant energy. In order to reduce the energy requirements for processing, as well as to improve product quality, reduce capital investment, and reduce manufacturing cost, attempts are being made to develop improved methods for making sheet. The new processes all involve some method of directly casting the molten steel into near final sheet/strip dimensions, so that only a small amount of further processing may be needed.

The potential payoffs for the nation - ultimately measurable in world-wide position in the steel market as well as in energy and cost savings - are considerable, and must be addressed as an important opportunity.

## MOTIVATION FOR RESEARCH AND DEVELOPMENT

### Energy Conservation

The domestic steel industry consumes about 5% of all fuel energy used in the United States. Much of it is derived from increasingly expensive fuel oil and natural gas rather than coal, although coal is still the steel industry's dominant energy resource. Approximately three quarters of the steel industry's energy consumption goes into iron-making, with hot and cold rolling consuming most of the balance. Thus 1 to 1.5% of all U.S. fuel energy goes to the conversion of steel ingot to the various products of hot and cold rolling mills. The prospect of eliminating most of the thermal energy now used for the rolling process in large part stimulated the present study on continuous casting of sheet/strip.

### Making U.S. Steel Industry More Competitive

In the 1950's the U.S. steel industry was the largest and most efficient in the free world. Today that place has clearly been lost to Japan, as shown in part by Fig. 1. Other Asian and European producers are also pressuring the U.S. with lower cost and higher quality. By 1980 the leading industrial countries of the world had made a substantial conversion from the ingot route to continuous casting of steel strand as shown in Fig. 2. Again, the preeminence of Japan is noteworthy. Indeed, in 1983 Japan exceeds a 70% continuous casting implementation rate, although the U.S. remains no better than 30%. The reasons for the relatively rapid conversion by many other countries include the reduced labor, energy, and capital costs while simultaneously product yield is improved and product quality enhanced. Symptoms of the general malaise in the domestic steel industry are the recurrent plant closings, corporate mergers, diversification activities, pleas for government protectionism, difficulty in attracting capital, import surges, and increasing technological obsolescence of the existing plant. The reasons adduced for this situation — high material and labor costs, lower costs for ocean shipping, foreign "dumping", environmental regulations, "downsizing" and decreased volume of domestic automobile production, material substitution and others — are highly varied and their relative importance hotly debated.

It is clear, however, that technological innovation in sheet steel making in principle has potential for contributing to a restored competitive position by realizing the benefits of energy conservation, reduced capital and operating costs, and of improved product quality and yield.

**Rapid development and commercialization of new direct steel sheet/strip casting technologies may allow U.S. to *leapfrog* the competition by converting directly from the obsolete ingot process to direct sheet/strip casting. Other leading steel producing countries with relatively new conventional continuous casting installations may not be so readily able to change to new technologies because of economic tradeoffs.**

**Development of direct sheet casting technologies combined with other near net shape casting technologies (e.g. billet) and direct reduction technology can help the U.S. take the vital step from conventional continuous casting to continuous steel making.**

### Large Steel Sheet/Strip Market

The fact that sheet and strip products account for nearly half of total domestic steel production places special emphasis on those technical developments which could increase the energy, capital and manufacturing cost savings in their processing.

## PROCESS INNOVATION

Most innovation in materials processing does not involve radically new processes but rather modifications of existing processes to permit, for example:

a) shift from batch to continuous process
b) increased automation
c) manufacturing or capital cost reduction
d) energy reduction
e) down-sizing or decentralization without loss of economy of scale
or f) increased product quality

The concept of continuously casting steel to yield a semifinished sheet or strip product directly from molten metal embraces at once all of these capabilities, each of which has become increasingly important because of the difficult state of the economics of the U.S. steel industry.

Two separate developments in the past 20 years suggest that this concept might now be realizable. These are:

a) Roller Casting Technology (largely developed as ribbon casting for the preparation of amorphous ferrous materials) and

b) the successful commercialization of the continuous casting of steel to strand suitable for subsequent processing as billet, bloom or slab, depending on size.

The problem is that presently neither of these two developments yields a product that is dimensionally suitable as sheet or strip for commercial application. Thicknesses from roller casting technology are typically less than 0.010 inch and those from conventional continuous casting of the order of several inches, whereas what is wanted for semi-finished sheet or strip is of the order of 0.100 inch. Other shortcomings of the roller casting process as thus far developed are the inability to cast wide sheet and the unacceptably low throughput rate. In addition to the continuous casting processes now in commercial use either for the production of amorphous metal strip or for continuous casting of strand steel, several others have been explored and at least two are known to have reached a pilot stage of operation.

## CANDIDATE TECHNOLOGIES

The comparison between the new direct casting processes, the old ingot route and the conventional continuous casting process is shown schematically in Fig. 3. The potential for savings in energy, capital and labor cost is clear.

The General Electric Company Corporate Research and Development Center, acting as a technical consultant group under contract to the Department of Energy, has carried out a comprehensive technical and economic assessment of the new direct casting processes for sheet and strip which can be grouped into four generic categories shown in Table I. These processes are schematically shown in Figures 4, 5, 6 and 7, and a detailed description and evaluation of these processes is given in General Electric's report prepared for the Department of Energy.* Only the principal findings are summarized here.

A pictorial comparison of the thickness-width ranges covered by hot and cold rolled sheet and strip, the current capabilities of the new rapid solidification processes and conventional continuous strand casting technology, and projected trends of the new technologies are shown in Figure 8. Goals for the new process technology based on end user need are given in Table II.

Results of the capital cost, relative operating cost and energy savings analysis are given in Tables III and IV. Some specific problems with candidate technologies are listed in Table V.

It is obvious from Tables III to V that the different candidate technologies have different risk-payoff trade-offs. Payoffs are either in terms of more favorable process economics; reduced capital, operating and energy costs as cited in Tables III and IV; or applicability to the largest markets as shown in Table II. Risks are associated with technical problems summarized in Table V as well as scale-up, operational and process control problems.

Table VI shows relative risk-payoff ratings and relative ranking of various processes. The table shows that two processes stand out:

- The *Single Roller Process* which has high payoff and good success probability.
- The *Twin Belt Process* which has somewhat lower payoff, but higher probability of success.

These two processes are also at much advanced stages of development than other processes.

Payoffs from new direct sheet casting processes are estimated to be the following:

| | |
|---|---|
| Energy Reduction: | $20 to 60/ton of steel |
| Capital Cost Reduction: | 40 to 70% as compared to cost of capital equipment for ingot and conventional continuous casting and subsequent rolling. |
| Manufacturing Cost Reduction: | 40 to 50% as compared to ingot casting and subsequent rolling |

## RECOMMENDATIONS

### 1. Process Recommendation

It is recommended that both the single roller casting and the twin belt casting processes with accompanying in-line hot rolling be developed to approach the desired product thickness from two opposite directions: thinner than desired - as the higher risk, higher payoff option; and thicker than desired - as the more conservative, somewhat lower payoff option, respectively. Consideration of the tradeoff between market needs and process capabilities, formal decision analysis and technical assessment of existing data do not support recommendation for a single process.

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*J.D. Desai, J.H. Westbrook, J.T. Heinen, A.M. Mankus and R.S. Miller, "Technology Development of Thin Strip Metal Casting," Report No. DOE/CE/12445, U.S. Department of Energy, January 1984.

The advantages and disadvantages of the two recommended processes may be contrasted as follows:

| Twin Belt Process | Single Roller Casting Process and its variations* |
|---|---|
| • two good surfaces, microstructure symmetry | one good surface, microstructural gradient* |
| • low scale-up risk in achieving product | high scale-up risk in achieving width *and* thickness dimensions required |
| moderate investment, manufacturing, and energy cost | • lower investment, manufacturing, and energy cost |
| • high throughput rate | • possibility of flexible throughput rate |
| • depth and breadth of industrial experience by steel companies | little industrial experience by steel companies |
| moderate in-line rolling required | • less in-line rolling required |

• Denotes advantage

2. **Required Development Effort**

Before major effort is committed to a demonstration program, a 1-2 year research program should be directed to a series of critical experiments directed at the two leading processes. These technical problems *must* be resolved *prior* to any major undertaking, e.g. pilot plant.

| Twin Belt Process | Single Roller Casting Process and its variations |
|---|---|
| **identify technical problems limiting minimum thickness. Evaluate any secondary cooling requirements** | **determine what problems a structural gradient and surface finish pose for further rolling and other processing** |
| **establish whether process can be economically and reliably coupled to a high reduction in-line mill** | **establish the maximum practical thickness at economic throughput rates** |
| **define and circumvent if necessary adverse effects of impurity flotation** | **establish the maximum practical width at economic throughput rates** |
| **evaluate metal feed and distribution problems associated with nozzle design and material**<br>**• dimensional stability**<br>**• contamination of cast sheet by erosion products** | **evaluate and solve nozzle problems expected with broad thin orifices**<br>**• dimensional stability**<br>**• plugging**<br>**• contamination of cast sheet by erosion products** |

---

*It is considered possible that variations in the single roller process such as addition of a small auxiliary roll could reduce any deficiencies due to surface condition and microstructural asymmetry.

| Twin Belt Process | Single Roller Casting Process and its variations* |
|---|---|
| **evaluate belt coatings and possible belt sticking and belt life problems** | **evaluate roller and nozzle materials and equipment design** |

determine what post-casting rolling is required to achieve satisfactory structure & properties

ascertain whether in-line coiling is feasible for required dimensions and throughput rate

determine what edge treatment is required (slitting, scarfing etc.)

determine for the state-of-the-art product

- rolling characteristics and tolerance
- mechanical properties
- forming characteristics, as-cast and rolled

The five items in bold type above for each process are viewed as having the highest priority in defining the field of applicability and probable payoff for the candidate technologies.

### 3. Cooperative Team Effort

To enhance the prospects for success of the development/demonstration program it is recommended that the organizational team selected include a steel company *and* a company with experience in building continuous casting (or similar process) equipment. University participation may also be significant. **The importance of a cooperative program cannot be overemphasized.**

### 4. Diversify Steel Products Targeted for Development

There are additional opportunities for economic and competitive gain in direct casting of other steel products such as billets. Such work is being done in Japan and more attention should be given to this in the U.S.

## SUMMARY

In summary, two processes, twin belt and single roller, are recommended for further development. It is also recommended that the technical problems be resolved in development prior to any major undertaking. The importance of a cooperative program has been emphasized.

# JAPANESE DEVELOPMENTS IN DIRECT SHEET CASTING*

## SUMMARY

Japan is the world leader in conventional continuous casting of steel. Thus it is not surprising that Japanese industry has also been active in developing direct sheet/strip casting processes. Several Japanese steel companies and at least one equipment manufacturer have been actively working for the last five years on at least three different direct casting processes and a number of pilot plants are in place. It appears that we may see commercial production in Japan by new direct casting processes in the next 3-6 years.

At least two steel companies now have pilot plants on the **twin belt process.** One of these companies is teamed with a major Japanese equipment manufacturer, who has reportedly been working on the development of a twin belt casting machine for the last two years. Slab, 1.6 inch thick (possibly thinner) x 24 inch wide has been cast from low carbon steel at 16 ft/minute. Future work will include increasing the width (to 48 inch and wider), reducing the thickness and simultaneously increasing the speed. The initial target of the current work appears to be the production of low quality (non deep-drawing) cold rolled and hot rolled low carbon steel sheet. The production rate from one casting machine is expected to be around 50,000 tons/month (compared with that of 2-strand conventional continuous casters of approximately 200,000 tons/month). The current plan appears to be coupling of two twin-belt casting machines with one finishing stand of rolling mills.

A number of companies and at least one university are actively working on the **double/twin roller processes.** There is at least one pilot plant in place for producing silicon iron. The operation of this pilot plant is expected to be concluded in 1984, during which time it will have supplied silicon iron for testing by the electrical industry. Commercial production may begin in 4 years. The pilot plant typically produces 0.020 inch thick x 8 inch wide silicon iron sheet with magnetic properties superior to those of conventional silicon iron. The plan is to cast sheet which can be continuously annealed and wound without any intermediate rolling. The production goal is 5,000 to 50,000 tons/year of higher-priced specialty steels like silicon steel, which are difficult to deform by rolling process, and will greatly benefit from direct casting.

The **rotary (wheel belt type)** caster is represented by one small commercial plant casting specialty steel billet.

It appears that the trend in Japan for as-cast products less than 4 inch thickness is towards development of moving-mold casting processes as opposed to stationary mold in conventional continuous casting. Thicknesses in the upper part of this range (0.2 to 1 inch) may be produced by double/twin roller or other processes derived from Rapid Solidification Technology. In April 1984, Iron and Steel Institute of Japan will form a special committee to study Rapid Solidification processes as applied to commercial steels with approximately 25 participating members from steel companies and universities. In any event, it appears that we may see commercial production in Japan by new direct casting processes in the next 3-6 years.

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*The observations summarized here are the result of a recent tour by the author of leading Japanese centers for continuous casting technology.

The significant observations to be made from this brief review of current Japanese effort in direct sheet casting are:

- The **diversity** of current work: many different product forms, and at least three different processes.
- The **cooperative nature** of the enterprise - involvement of steel companies, equipment builders, and universities.
- The work on **premium grade** specialty steel.

In view of the advanced state of continuous casting technology in Japan and these aspects of current activity in direct sheet casting, it must be concluded that Japanese competition for the sheet steel business looms as a significant threat to U.S. steel producers.

## TABLE I

## CLASSIFICATION OF CANDIDATE PROCESSES FOR CONTINUOUS CASTING OF STEEL SHEET/STRIP

- CONVENTIONAL CONTINUOUS CASTING WITH STATIONARY MOLD

- CONTINUOUS CASTING WITH MOVING MOLD
    - TWIN BELT
    - WHEEL-BELT
    - INSIDE-THE-RING
    - TWIN ROLLER

- ROLLER CASTING PROCESSES
    - SINGLE ROLLER AND ITS VARIATIONS
        - MELT SPINNING
        - PLANAR FLOW CASTING
        - MELT DRAG
    - TWIN ROLLER

- SPRAY ROLLING

## TABLE II

## END USER REQUIREMENTS
## GOALS FOR NEW PROCESS TECHNOLOGY

| | |
|---|---|
| THICKNESS | 0.020 - 0.080 IN. |
| WIDTH | 35 - 60 IN. |
| QUALITY | STANDARD OR COMMERCIAL QUALITY, |
| | MEETS INDUSTRY STANDARDS FOR FORMABILITY |
| TYPE | LOW CARBON STEEL (AISI 1008/1010) |
| FINISH | CLASS 1 |

## TABLE III

## CASTING EQUIPMENT COST, RELATIVE OPERATING COST AND ENRGY USAGE OF CANDIDATE TECHNOLOGIES[a]

| | Ingot Casting | Conventional Continuous Casting with Stationary Molds | Continuous Casting with Moving Molds | | | Roller Casting | | |
|---|---|---|---|---|---|---|---|---|
| | | | Twin-Belt | Wheel-Belt | Inside-the-Ring$^{(b)}$ | Single Roller$^{(b)}$ | Twin Roller$^{(b)}$ | Spray Rolling$^{(b)}$ |
| Casting Equipment Approximate Cost (Millions of $) | – | $50-100 | 3.5-4 | <4 | <10$^{(c)}$ | ~ 5-10 | ~ 12 | ~ 9$^{(c)}$ |
| Section Cast: Thickness x Width (Inch) | – | 4 to 12 x 6 to 118 also 2" square | 1 x 30 | 1.25-2.125 x 3-4.25 | 0.150-0.350 x 15 | 0.010 x 4 to 0.016 x 7 | 0.020 x 14 | – |
| Casting Speed, Ft/Min | – | 8-10 | 30-40 | 45 | 25 | ~ 1000 | – | 36 |
| Current Production Capacity, Ton/Hr | – | 25-380 | 75-120 | 35 | 12 | ~ 4-12 | ~ 8 | 60 |
| Approximate Energy Savings Over Ingot Casting | 0 | >10% | >16% | >15% | >20% | >20% | >20% | >16% |
| Relative Operating Cost | Highest | Higher | High | High | Medium | Low | Low | Medium(?) |

(a) See Table IV for detailed projection of equipment cost.
(b) Based on laboratory or pilot-scale equipment.
(c) Uses controlled atmosphere. Cost estimates are very approximate.

## TABLE IV

## PROJECTED EQUIPMENT COST BASED ON NORMALIZED PRODUCTION CAPACITY FOR CANDIDATE TECHNOLOGIES[a]

| Candidate Technology | Target As-Cast Thickness, Inch | Projected Casting Speed Ft/Min | Projected Equipment Cost (millions of $) | | | | | Projected Capacity |
|---|---|---|---|---|---|---|---|---|
| | | | Casting | Hot Rolling | Cold Rolling | Pickling$^{(f)}$ Auxiliary Controls, Trimmers, etc. | Total Cost | |
| Conventional Continuous Casting with Stationary Molds | 7 possibly 1-2 | ~10 | 1@>200 Ton/Hr<br>1x$50-100=<br>$50-150 | Roughing + Finishing mill ~$250 | Standard Cold-mill$^{(e)}$<br>$50 | $33 | $383-433 | >200 Ton/Hr |
| Continuous Casting with Moving Molds | | | | | | | | |
| Twin-Belt | 1 | 30-40 | 1@$250 Ton/Hr<br>1x$3.5-4=$3.5-4 | Heavy Reduction$^{(c)}$ at 200 Ton/Hr<br>1x$30=$30 | Standard Cold-mill$^{(e)}$<br>$50 | $33 | $147 | 200 Ton/Hr |
| Wheel-Belt | 0.5 | 55 | 3@60 Ton/Hr<br>3x<$4=<$12 | 3 Heavy Reduction$^{(d)}$ at 60 Ton/Hr<br>3x$25=$75 | Same<br>$50 | $8 | $170 | 180 Ton/Hr |
| Inside-the-Ring | 0.1-0.4 | 110 | 1@156 Ton/Hr<br>1x$10=$10 | 3-4 Hot Stands<br>$50-70 | Same<br>$50 | >$33 | $143-163 | 156 Ton/Hr |
| Roller Casting Processes | | | | | | | | |
| Single Roller$^{(b)}$ | 150 | >1000 | 1@>250 Ton/Hr$^{(b)}$<br>1x$5-10=$5-10 | 1-2 Hot Stands(?)<br>$20-40 | Same<br>$50 | $33 | $108-133 | >250 Ton/Hr |
| Twin Roller$^{(b)}$ | 150 | >1000 | 1@250 Ton/Hr$^{(b)}$<br>1x$12=$12 | 1-2 Hot Stands(?)<br>$20-40 | Same<br>$50 | >$33 | $115-135 | >250 Ton/Hr |
| Spray Rolling | 0.25 | ~36 | 1@240 Ton/Hr<br>$10-12 | 3-4 Hot Stands<br>$50-70 | Same<br>$50 | $33 | $143-165 | 240 Ton/Hr |

(a) Hot rolling, cold rolling and pickling equipment costs are supplied by leading equipment manufacturers. Capacities are made approximately equivalent at a level of about 200 tons/hr. Final product thickness from cold rolling mill is assumed to be same for all technologies, 0.050-0.100 in.
(b) Based on laboratory or small pilot-scale equipment. Currently these two processes can produce very thin and narrow products. It is assumed that when scaled-up for making 0.100" thick x 72" wide product, casting speed and equipment cost will not change significantly.
(c) Krupp Platzer Planetary mill
(d) Sendzimir Planetary mill
(e) Cold rolling mill at approximately 500 Ton/hour
(f) Pickling equipment at approximately 500 Ton/hour

## TABLE V SOME SPECIFIC PROBLEMS WITH CANDIDATE TECHNOLOGIES

| Parameter | Continuous Casting with Moving Molds | | | Roller Casting Processes | | |
|---|---|---|---|---|---|---|
| | Twin Belt | Wheel-Belt | Inside-the-Ring | Single Roller | Twin Roller | Spray Rolling |
| Processing Parameters | Uniform metal distribution<br>In-line rolling with heavy reduction mill possible? — feasibility, reliability, economics<br>Limited belt life | Limited belt life<br>Belt sagging for wide sheets? Width limitation?<br>Mold change for width, thickness change | Atmospheric control<br>Extraction problem on wide sheets particularly at high speed, width limitation? | In-line rolling or coiling problems due to high speed<br>Max. width, thickness limitation? | Metal flow problem?<br>Excess freezing at ends<br>Maximum width and thickness limitation | Atmospheric control required<br>In-line rolling possible?<br>Multiple nozzle feasibility needed for wide sheets |
| Product Quality Parameters | Impurity flotation to top<br>Center line shrinkage due to large as-cast thickness | | Difficult tolerance control on thin, wide products | One uncontrolled surface — directly rollable?<br>Microstructural gradient<br>Columnar Microstructure? | Difficult tolerance control on thin, wide products | Very rough surface<br>Porosity, maximum 98% dense<br>More porosity on edges |
| Process Control Window | | | Probably narrow, similar to twin roller? | | Narrow range of casting speed—. Liquid casting vs roll breaking<br>Small solidification zone, almost line contact | |
| Relative Scale-up Risk | Low | Low | Medium to high? | Medium | High | Medium to High |

## TABLE VI

## SUMMARY OF RELATIVE RANKING AND RISK-PAYOFF ANALYSIS

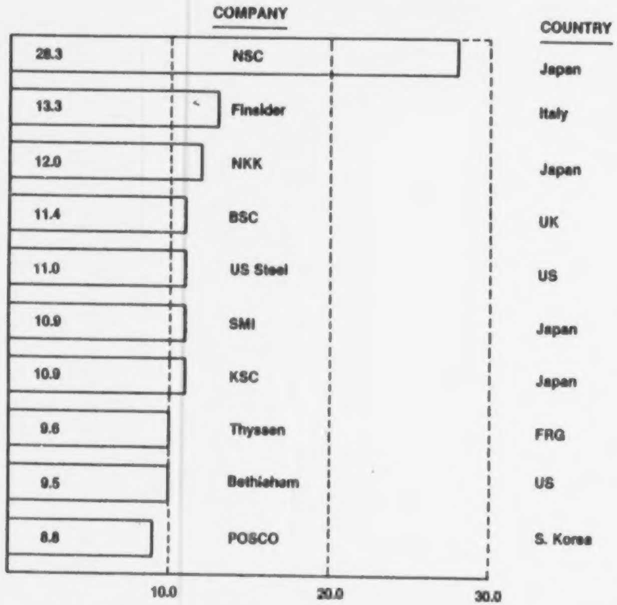
### EVALUATION CRITERIA

- MELT-TO-STRIP PROCESSING
  - TECHNICAL FEASIBILITY
  - METAL DELIVERY AND HANDLING
  - PROCESS CONTROL REQUIRED
  - POST-CAST PROCESSING REQUIRED
- STRIP QUALITY
- PROCESS SCALE-UP
- ECONOMICS

### RISK-PAYOFF ANALYSIS

| PROCESS RANKING FOR DIRECT SHEET CASTING | | RELATIVE PAYOFF | RELATIVE RISK |
|---|---|---|---|
| TWIN-BELT | 1 | LOW TO MEDIUM | LOW |
| SINGLE ROLLER AND VARIATIONS | | HIGH | MEDIUM |
| INSIDE-THE-RING | 2 | MEDIUM | MEDIUM TO HIGH |
| TWIN ROLLER | | HIGH | HIGH |
| SPRAY ROLLING | 3 | LOW TO MEDIUM | MEDIUM TO HIGH |
| WHEEL BELT | | LOW | LOW TO MEDIUM |

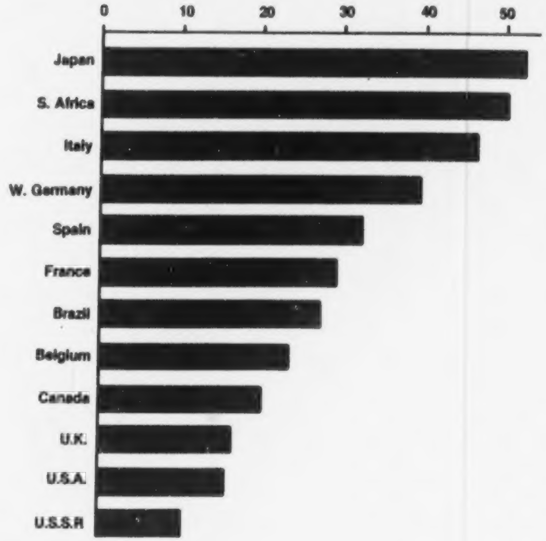
STEEL SHIPMENTS*



*MILLIONS OF METRIC TONS (SOURCE/IISI; 1982)

Fig. 1 World's top ten steel-producing companies in 1982. The USSR is excluded (~150 million tons). The ten companies shown plus the USSR account for nearly half the world's total steel production. Steel production capacity, however, is much greater, by at least a factor of two.

CONTINUOUS CASTING RATE (%) IN VARIOUS COUNTRIES, 1980



Source: IISI

Notes: 1) Countries having CC output of 3 million tons

2) CC rate = $\frac{\text{CC semi-finished steel}}{\text{Crude steel output}}$

Fig. 2 Comparison of the degree to which various nations have converted from ingot to continuous casting for steel production as of 1980.

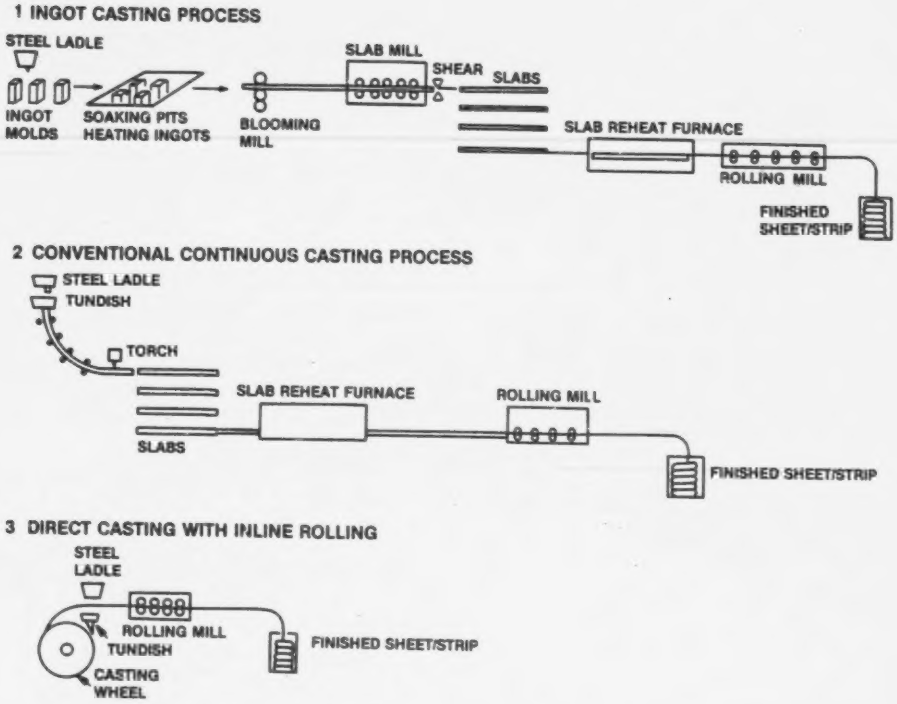

1 INGOT CASTING PROCESS
STEEL LADLE
INGOT MOLDS
SOAKING PITS HEATING INGOTS
BLOOMING MILL
SLAB MILL
SHEAR
SLABS
SLAB REHEAT FURNACE
ROLLING MILL
FINISHED SHEET/STRIP
2 CONVENTIONAL CONTINUOUS CASTING PROCESS
STEEL LADLE
TUNDISH
TORCH
SLAB REHEAT FURNACE
ROLLING MILL
SLABS
FINISHED SHEET/STRIP
3 DIRECT CASTING WITH INLINE ROLLING
STEEL LADLE
ROLLING MILL
TUNDISH
CASTING WHEEL
FINISHED SHEET/STRIP

Fig. 3 Schematic comparison of direct, conventional continuous and ingot casting.

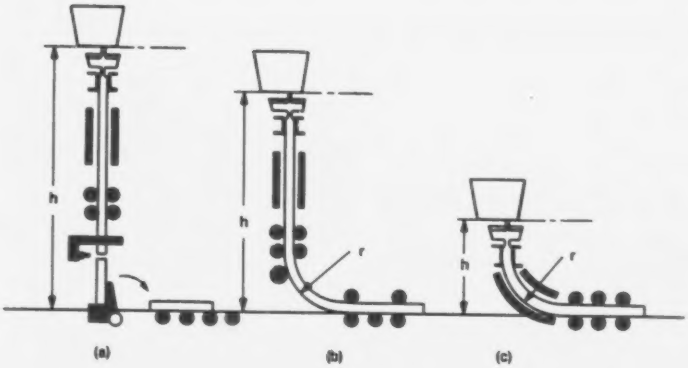
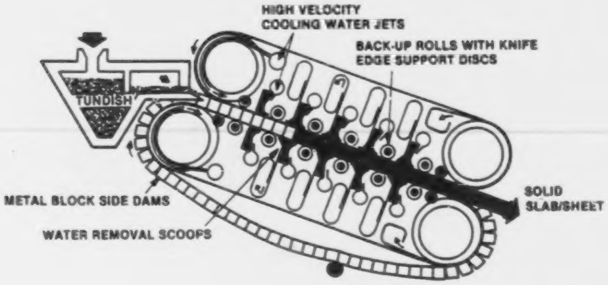
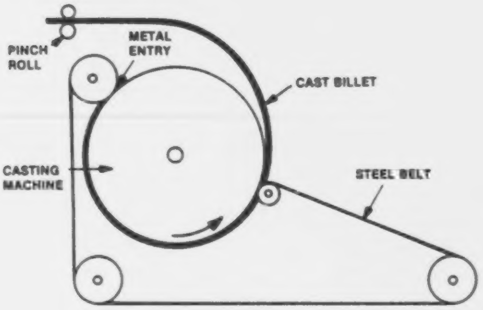


Fig. 4 Schematic representation of the three stages in the development of stationary mold, continuous casting machines: a) vertical casting and cut off; b) vertical casting and bending to cut off; c) curved mold machine.

5(a). TWIN-BELT


HIGH VELOCITY COOLING WATER JETS
BACK-UP ROLLS WITH KNIFE EDGE SUPPORT DISCS
TUNDISH
METAL BLOCK SIDE DAMS
WATER REMOVAL SCOOPS
SOLID SLAB/SHEET

5(b). WHEEL-BELT


PINCH ROLL
METAL ENTRY
CAST BILLET
CASTING MACHINE
STEEL BELT

5(c). INSIDE-THE-RING

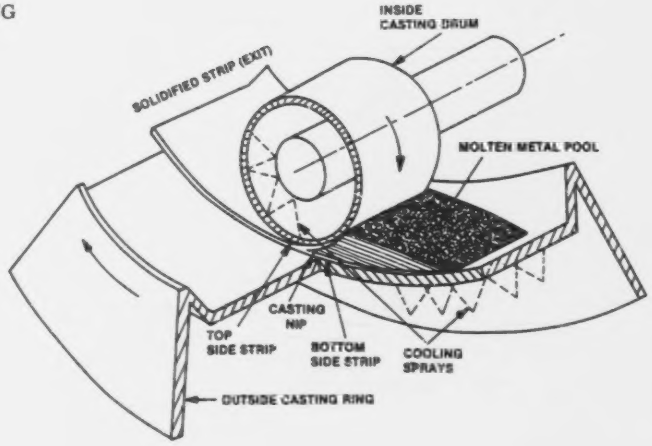

INSIDE CASTING DRUM
SOLIDIFIED STRIP (EXIT)
MOLTEN METAL POOL
CASTING NIP
TOP SIDE STRIP
BOTTOM SIDE STRIP
COOLING SPRAYS
OUTSIDE CASTING RING

Fig. 5 Schematic of continuous casting processes with moving molds

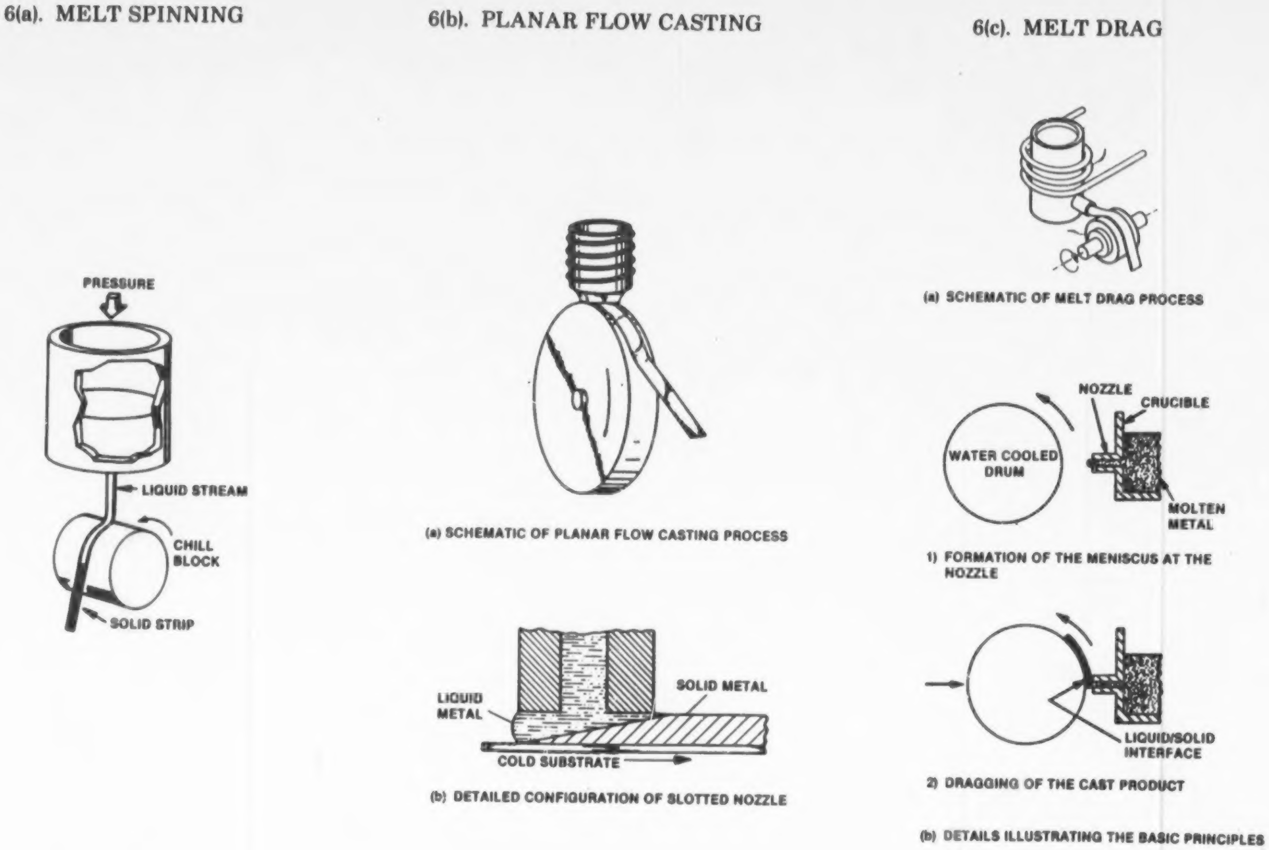

6(a). MELT SPINNING
PRESSURE
LIQUID STREAM
CHILL BLOCK
SOLID STRIP
6(b). PLANAR FLOW CASTING
(a) SCHEMATIC OF PLANAR FLOW CASTING PROCESS
LIQUID METAL
SOLID METAL
COLD SUBSTRATE
(b) DETAILED CONFIGURATION OF SLOTTED NOZZLE
6(c). MELT DRAG
(a) SCHEMATIC OF MELT DRAG PROCESS
NOZZLE
CRUCIBLE
WATER COOLED DRUM
MOLTEN METAL
1) FORMATION OF THE MENISCUS AT THE NOZZLE
LIQUID/SOLID INTERFACE
2) DRAGGING OF THE CAST PRODUCT
(b) DETAILS ILLUSTRATING THE BASIC PRINCIPLES

Fig. 6. Schematic of Single Roller Casting Process and Its Variations

## 6(d). TWIN/DOUBLE ROLLER

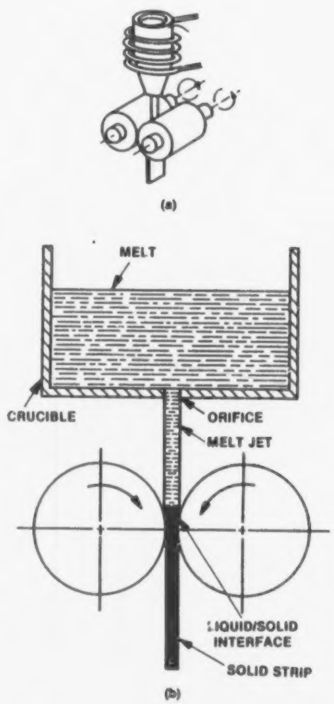

(a)
MELT
CRUCIBLE
ORIFICE
MELT JET
LIQUID/SOLID INTERFACE
SOLID STRIP
(b)

Fig. 6 (Cont'd)

## SPRAY ROLLING

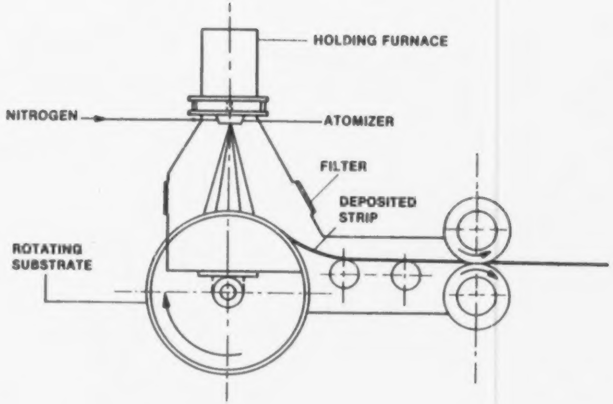
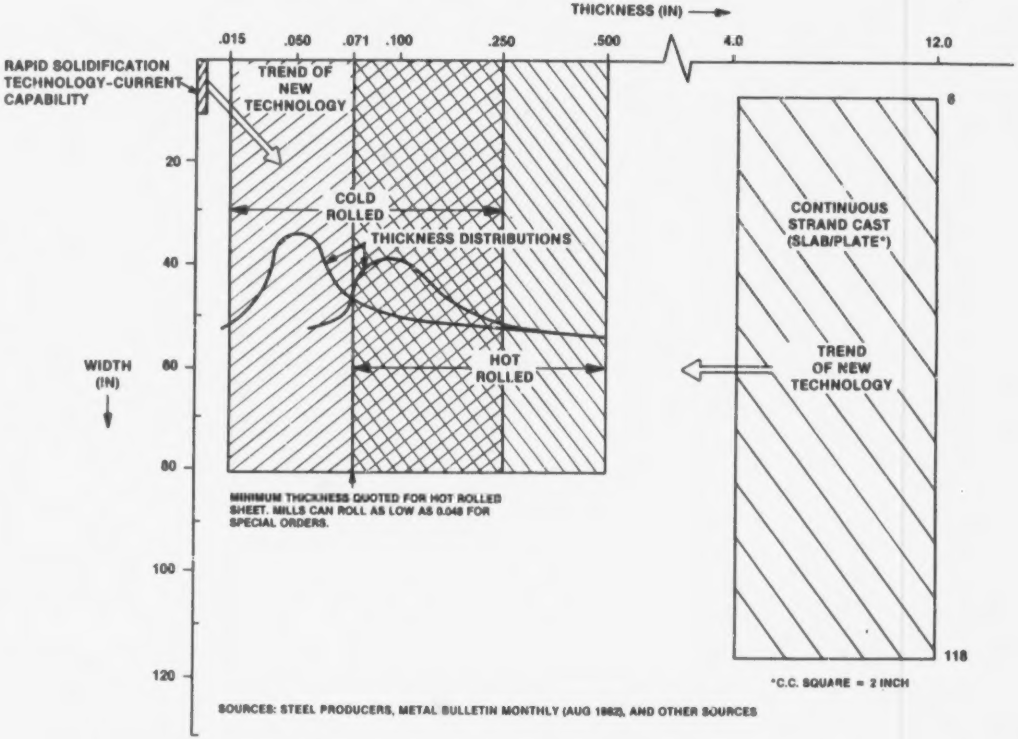

HOLDING FURNACE
NITROGEN
ATOMIZER
FILTER
DEPOSITED STRIP
ROTATING SUBSTRATE

Fig. 7 Schematic of the spray rolling process.



SOURCES: STEEL PRODUCERS, METAL BULLETIN MONTHLY (AUG 1982), AND OTHER SOURCES

Fig. 8 Thickness-width ranges covered by hot and cold rolled sheet and strip, continuously cast strand, rapid solidification technology and the projected trends of the new technologies.

Mr. **Fuqua**. Thank you very much, Dr. Desai.

Dr. Carlsmith.

## STATEMENT OF DR. ROGER S. CARLSMITH, DIRECTOR, CONSERVATION AND RENEWABLE ENERGY PROGRAM, OAK RIDGE NATIONAL LABORATORY

Dr. **Carlsmith**. Thank you, Mr. Chairman.

I do request, also, that my statement be inserted in the record.

It is a pleasure for me to be here today to discuss with you some of the research we are doing for the Department of Energy.

The program at Oak Ridge includes projects aimed at improving the efficiency of energy use in all sectors of the U.S. economy—residential, commercial, industrial, and transportation. We have approximately 110 scientists and engineers from our technical staff assigned to this program. In addition, we subcontract substantial portions of the work to universities and industry.

During the 14 years of ORNL research in conservation and renewables, we have taken a number of technologies all the way from the researcher's original idea to the point at which they are ready for use. Several of our developments are now incorporated in commercially available products, including a heat pump water heater, an improved compressor for home refrigerators, and an energysaving process for the manufacture of the ceramic material, silicon carbide.

As we have proceeded, we have been impressed with the large number of additional opportunities that exist for improving the efficiency with which we use energy. For instance, a recent DOE analysis concludes that research opportunities have been identified for reducing energy use by 34 percent.

While it is true that we can use available technology to make many improvements, it will take a sustained program of research by Government and industry to maintain and improve the competitive position of the economy.

In the time available today, I will discuss two conservation research areas as illustrations of our larger program. The first area is the research systems portion of technology and consumer products. By the term refrigeration systems, we mean electrically driven heat pump and air conditioning equipment used to provide heating or cooling for buildings. Refrigeration systems are also used in major appliances such as refrigerators and freezers.

The importance of this area is underscored by the fact that heating and cooling accounts for 22 percent of the country's total energy use. Nearly all cooling systems and about one-fifth of the new installations use the electrically driven heat pump principle.

Although heat pumps are the most efficient way of using electricity for heating and cooling, they tend to suffer from one major shortcoming; namely, their capacity and efficiency decrease as the outdoor temperature drops. Thus, the system is less useful when it is most needed.

Over the past several years, we have investigated the energy use of commercially available heat pumps and have explored several avenues for improved technologies. One advanced design is now being tested by Westinghouse under subcontract to ORNL. This heat pump has a dual-stroke compressor which allows it to operate efficiently over a wide range of outdoor temperatures. It is achieving an efficiency about 25 percent higher than the best heat pump now on the market.

A principal activity of our research program has been the development of a computer model for optimizing heat pump design. This model is being used to diagnose the causes for inefficiency in individual heat pump components. It is proving extremely useful in analyzing the performance of technologies such as the one being tested at Westinghouse. Our computer model has also proved useful to other organizations. Thus far, we have supplied copies of it to 70 other organizations.

Other approaches to obtaining high efficiency may eventually prove even better than the use of a dual-stroke compressor. One concept is the ground-coupled heat pump which uses buried pipes to extract heat from the ground rather than using the heat from outdoor air. Tests done in collaboration with Brookhaven Lab and the Niagara Mohawk Power Co. have shown that these systems can operate with as much as 40 percent greater efficiency than air-source heat pumps.

However, at present, ground coils are expensive, and there are no reliable design methods for determining the size of the coils. The work now under way at ORNL is scheduled to yield a comprehensive design procedure by the end of fiscal year 1985.

Another way of getting a high efficiency heat pump for cold climates is to use a mixture of two kinds of freon instead of a single type. The mixture can provide higher capacity at low temperatures when more heat is needed. Experiments using this concept are now under way and are scheduled to be completed by the end of fiscal year 1986.

The common thermal insulation materials used for appliances such as refrigerators and water heaters are fiberglass batts or urethane foam. These materials have R-values of 3 and 7 per inch. We have been working on the development of an advanced insulation material composed of compressed microscopic silica particles. We believe that such materials can be developed that will have R-values of 15 per inch in air and perhaps 20 per inch in evacuated panels, thus making possible substantial reductions in energy consumption by the appliances.

I have brought with me some samples of some of the research developments that I have been talking about. I think it may help you to visualize what some of these materials are. This is a sample of the powder that I was just referring to which will be a super insulation.

I have described only a few examples of our current work in refrigerations systems. Others are covered in my written statement.

This program is one in which we are proud. We have produced results which are being used to save energy. We are now doing research on additional approaches which may lead to still larger energy savings, and we have identified future research which would be likely to benefit the country.

In each of these projects, we are working closely with the manufacturing industry, electric utilities, and the Electric Power Research Institute to ensure that the research is needed and that it is made known to potential users.

During the past year, we have sought the advice of most of the major heat pump manufacturers in defining our future program and in evolving effective means for technology transfer between Government and industry. The recent building equipment energy workshop at Airlie House provided useful interactions. The draft report from that workshop indicates that the DOE program is in areas which the industry considers appropriate for Government funding.

Before leaving the subject of heat pumps, I would like to mention that we also manage the DOE program in thermally activated heat pumps. We are attempting here to develop technology for using natural gas to heat and cool more efficiently than at present.

A recent breakthrough in absorption cycle technology may allow much higher efficiencies than were previously thought possible. This area is particularly important because of the increasing intensity of foreign competition on absorption heat pumps, particularly from the Japanese.

I will now turn to a second area in which ORNL operates as DOE field manager. This is the Materials and Tribology Projects of the Energy Conversion and Utilization Technologies Program, commonly referred to as ECUT.

The objective of these projects is to accomplish the long-range applied research and exploratory development on materials and tribology. Tribology is a technical term for the friction and wear behavior of materials.

These projects apply scientific theory and research tools developed in the basic research programs of DOE and NSF and apply them to the needs of advanced conservation systems. Thus, the ECUT projects serve as a bridge between fundamental research and engineering development programs. This is an extremely important bridge that has been lacking in earlier DOE programs, as pointed out in the recent report of the Energy Research Advisory Board.

The ECUT materials project was established in fiscal year 1981. We first made an assessment of materials technology needs for advanced conservation systems in cooperation with industry, universities, and other Government offices. Materials developments were sought which could substantially increase energy efficiency through higher operating temperatures and pressures, reduce losses from friction, and reduce energy in producing materials.

Our evaluation criteria emphasize high energy savings, low development cost, no duplication of other government or industry research, and high potential for technology transfer to industry.

I will now describe some of the accomplishments of the research to date and show the interaction of ECUT with basic research, conservation applications, and industry. In high temperature materials, ECUT is developing innovative approaches for development of improved metal alloys, toughened ceramics, composites, and joints.

For example, intermetallic compounds based on the nickel aluminide system were previously thought to be inherently brittle and have low strength. However, fundamental crystal theory, developed as long ago as 1969, pointed the way to a new class of alloys which are strong and corrosion resistant even at high temperatures and yet are relatively easy to fabricate.

The key has proved to be the addition of small quantities of other elements which reduce the tendency of the material to come apart at grain boundaries. These alloys have great potential for increasing the efficiency of advanced energy conversion systems, including turbines, Stirling and diesel engines, recuperators for waste heat recovery, and solar energy storage systems.

Based on these results, the conservation end-use programs, other DOE offices, and industry are now starting to fund the technology development and scale-up of these alloys for specific applications. The ECUT program will continue its exploratory development of these alloys over the next 2 years.

I also brought some samples of the nickel aluminide showing the material in its originally very brittle state and then also showing samples of it as we have developed it to a more ductile form.

Another ECUT high temperature materials development task has shown that the toughness of high-temperature ceramics can be substantially improved by adding high-strength ceramic whiskers to the ceramic matrix. Both the toughness and strength of aluminum oxide can be more than doubled by using 20 to 30 percent silicon carbide whiskers.

Because of the importance of this development to adiabatic diesel engines, the further development of this ceramic composite material has been transferred to the DOE Office of Vehicles and Engine R&D.

A second major ECUT materials work element focuses on lightweight materials. The increasing use of plastics in automobiles increases the amount of petroleum feedstock required for the plastics and also creates a problem with the disposal of plastic scrap.

In a joint project with the Plastic Institute of America and several universities, compatibilizers have been developed to join and mold into useful products the variety of plastics that remained from the auto shredder process. ECUT has now transferred responsibility for this development to the Office of Industrial Programs in DOE, which is funding a demonstration in scrap yards across the country in cooperation with the Scrap Dealers Association.

Here is an example of the kind of thing that was produced in this program. This little sample parts bin was produced from shredded automobile plastic and fiber scrap.

The American Society of Mechanical Engineers estimated in 1977 that as much as 11 percent of the energy consumption in the United States is used to overcome friction and wear losses. Because of the large energy saving potential in reducing friction and wear, a separate multidisciplinary ECUT tribology project was established in fiscal year 1983.

The major work elements are lubrication, tribological coatings, friction and wear testing, and design methodology. Research was started last year at the National Bureau of Standards on the lubricating qualities of oils. This work has shown for the first time which constituents of oils actually control friction.

A second result has been the development of a simple test which predicts with reasonable accuracy how well a lubricating oil will work in an engine. This research may give the oil industry information leading to improved lubricants.

In another project, Argonne National Laboratory is leading the work for ECUT on tribological coatings. The aim here is to develop coatings for parts such as bearings, which will permit them to operate with less friction and longer life.

During the past year, a workshop was held, priorities were established, and initial research was started.

In summary, I have indicated the importance of the ECUT projects to a range of conservation applications. Because of the close interface of ECUT with both basic research and applied programs, highly productive research can be accomplished rapidly. However, we have been able to work on only a small fraction of the high priority tasks that have been identified.

With the management teams and working interfaces that have been established over the past 3 years, ECUT projects are now in excellent position to effectively expand and to capitalize on basic research results to increase the energy efficiency and productivity of the country.

Thank you.

[The prepared statement of Dr. Carlsmith follows:]

# ORNL RESEARCH PROGRAMS

on

# Refrigeration Systems ECUT Materials and Tribology

Roger S. Carlsmith
Director Conservation and Renewable Energy Program
Oak Ridge National Laboratory*
Oak Ridge, Tennessee 37831

Testimony to the
Subcommittee on Energy Development and Applications,
Committee on Science and Technology,
U.S. House of Representatives

Hearing on the FY 1985 Authorization for the
Department of Energy's Conservation
Research and Development Programs

February 29, 1984

*Operated by Union Carbide Corporation under Contract No. W-7405-eng-26 with the U.S. Department of Energy, Oak Ridge, Tennessee.

My name is Roger S. Carlsmith. I am Director of the Conservation and Renewable Energy Research Program at the Oak Ridge National Laboratory (ORNL). It is a pleasure for me to be here today to discuss with you some of the exciting research we are doing for the Department of Energy. Our program at ORNL in-cludes projects aimed at improving the efficiency of energy use in all of the sectors of the U.S. economy: residential, commercial, industrial, and transportation. Approximately 110 scientists and engineers from the ORNL technical staff are assigned to the program. In addition, we subcontract substantial portions of the work (about 55%) to universities and industry in order to obtain experts in each field and also to obtain the involvement of industry at an early stage of the research. Frequently, the subcontracts with industry include provisions for cost-sharing between DOE and the industrial participant.

During the fourteen years of ORNL research in conservation and renewable energy, we have taken a number of technologies all the way from the researcher's original idea to the point at which they are ready for use. Several of our developments are now incorporated in commercially available products, including an energy-efficient heat pump water heater by EUS, Inc., an improved compressor for home refrigerators by the Kelvinator Corp., an efficient refrigerator-freezer by the Amana Corp., and an energy-saving process for the manufacture of the ceramic material, silicon carbide. As we have proceeded with our research, we have been impressed with the large number of additional opportunities that exist for improving the efficiency with which we use energy. For instance, a recent analysis by DOE concludes that research opportunities have been identified for reducing energy use by 34%, of which almost half might actually be achieved by the year 2000. While it is true that we can use available technology to make many improvements, it will take a sustained program of research by government and industry to maintain and improve the competitive position of the economy.

In the limited time available today, I will discuss two conservation research areas as illustrations of the larger program. The first area is the Refrigeration Systems portion of Technology and Consumer Products. By the term Refrigeration Systems we mean electrically-driven heat pump or air conditioning equipment used to provide heating or cooling for buildings. Refrigeration Systems are also used in major appliances such as refrigerators and freezers. The importance of this area is underscored by the fact that heating and cooling accounts for 22% of the nation's total energy use. Nearly all cooling systems and about one-fifth of the new installations of heating equipment use the electrically-driven heat pump principal. Although heat pumps are the most efficient means of using electricity for heating and cooling, they tend to suffer from a major shortcoming; namely, their capacity and efficiency decrease as the outdoor temperature drops. Thus the system is less useful when it is most needed.

Over the past several years, ORNL researchers have investigated the energy use of commercially available heat pumps, and have explored several avenues for improved technologies which would perform better at low temperatures. One advanced design is now being tested by Westinghouse under subcontract to ORNL. This heat pump has a dual-stroke compressor which allows it to operate efficiently over a wide range of outdoor air temperatures, and also has a number of other advanced features. It is achieving an efficiency about 25% higher than the best heat pump now on the market (a COP of 3.8 at 47°F.) Already, details of the work have been shared with the Electric Power Research Institute and the heat pump industry.

A principal activity of our research program has been the development of a computer model for optimizing heat pump design. This model is being used to diagnose the causes for inefficiency in individual heat pump components. The accuracy of the model has been checked extensively by comparison with heat pumps operating in our laboratories. This tool is proving extremely useful in analyzing the performance of technologies such as the one being tested at Westinghouse. Our computer model has also proved useful to other organizations. Thus far we have supplied copies of it to 70 organizations, 18 of which are heat pump manufacturers.

Other approaches to obtaining high efficiency may eventually prove even better than the use of a dual-stroke compressor. One concept is the ground-coupled heat pump which uses buried pipes to extract heat from the ground rather than obtaining heat from the outdoor air. Tests done in collaboration with Brookhaven National Laboratory and Niagara Mohawk Power Company have shown that these systems can operate with as much as 40% greater efficiency than air-source heat pumps. However, at present, ground-coils are expensive, and there are no reliable design methods for determining the size of coils needed for air conditioning. The work now underway at ORNL is scheduled to yield a comprehensive design procedure by the end of FY 1985.

Another way of getting a high efficiency heat pump for cold climates is to use a mixture of two kinds of Freon instead of a single type. (The technical term is nonazeotropic refrigerant mixture.) The refrigerant mixture can provide higher capacity at low temperatures when more heat is needed. Experiments using this concept are now underway and are scheduled to be completed by the end of FY 1986. Along with the development of variable capacity concepts we are starting to investigate the addition of a zone-control feature which would provide the capability to allow the heating or cooling to be shut off from unused portions of a building. (This cannot be done with present-day heat pumps because of the danger of damaging the equipment.)

The common thermal insulation materials used for appliances such as refrigerators and water heaters are fiberglass batts or polyurethane foam. These materials have R values of 3 and 7 per inch. We have been working on the development of an advanced insulation material composed of compressed microscopic silica particles. We believe that such materials can be developed that will have R values of 15 per inch in air and 20 per inch in evacuated panels, thus making possible substantial reductions in energy consumption by the appliances. An exciting possibility is that the material could also be used to insulate the exterior of buildings if it can be made inexpensively enough. While basic laboratory experiments on thermal properties have been encouraging, substantial work remains.

In the past, most of the activities in this program have been concerned with factory-assembled heating and cooling equipment for homes and small commerical buildings. This was because the field-assembled systems for large buildings are more diverse and consume less energy in aggregate. We feel that it is now time to turn our attention to the larger systems, which are also important energy consumers. Our immediate task is to establish an advisory group that will help us to define the problem areas and to formulate a national R&D plan for implementation cooperatively by equipment manufacturers, engineering firms, and the Federal Government. Estimates of potential savings by the application of advanced technology to commercial building equipment range from 25% to 35%.

The overall program of research on Refrigeration Systems is one of which we are proud. We have produced results which are being used to save energy. We are now doing research on additional approaches which may lead to still larger energy savings. And we have identified future research which would be likely to benefit the country. In each of these projects we are working closely with the manufacturing industry, electric utilities, and the Electric Power Research Institute to ensure that the research is needed and is made known to potential users. During the past year we have sought the advice of most of the major heat pump manufacturers in defining our future program and in evolving effective means for technology transfer between government and industry. The recent Building Equipment Energy Workshop at Airlie House provided useful interactions. The draft report from that workshop indicates that the DOE program is in areas which industry considers appropriate for government funding.

Before leaving the subject of heat pumps I would like to mention that we also manage the DOE program in thermally activated heat pumps. We are attempting to develop technology for using natural gas to heat and cool more efficiently than at present. A recent breakthrough in absorption cycle technology may allow much higher efficiencies than were previously thought possible. This area is particularly important because of the increasing intensity of foreign competition.

I will now turn to a second research area in which ORNL acts as DOE field manager. This consists of the Materials and Tribology Projects of the Energy Conversion and Utilization Technologies (ECUT) Program. The objective of these projects is to accomplish the long-range applied research and exploratory development on materials and tribology (friction and wear behavior) required for future energy conservation applications. These projects apply scientific theories and research tools developed in the DOE and NSF basic research programs to the needs of advanced conservation systems. These projects also pursue innovative ideas that do not fit within the scope of current end-use conservation programs. Thus, the ECUT projects serve as a bridge between fundamental research and engineering development programs. This is an extremely important bridge that has been lacking in earlier DOE programs, as pointed out in the recent Energy Research Advisory Board (ERAB) report.[1]

The ECUT Materials Project was established in FY 1981. We first made an assessment of materials technology needs for advanced conservation systems in cooperation with industry, universities, and other government offices. Materials developments were sought which could substantially increase energy efficiency through higher operating temperatures and pressures; reduced losses from friction, and reduced energy in producing materials. Our evaluation criteria emphasize high energy savings, low development cost, no duplication of other government or industry research, and high potential for technology transfer to industry. Next, a Guidance and Evaluation Board was established from industry, university, and other government agency representatives and a few of the highest priority research tasks were selected and initiated.

I will now describe some of the accomplishments of the research to date and show the interaction of ECUT with basic research, conservation applications, and industry. In the area of high temperature materials, ECUT is developing innovative approaches for development of improved metal alloys, toughened ceramics, composites, and joints. For example, intermetallic compounds based on the (Fe,Ni)$_3$V and Ni$_3$Al systems were previously thought to be inherently brittle and have low strength. However, fundamental crystal theory developed in 1969 and recent results from basic research experiments in Japan and at ORNL, have pointed the way to a new class of alloys which are strong and corrosion resistant, even at high temperatures, and yet are relatively easy to fabricate into complex shapes. The key has proved to be the addition of small quantities of other elements which reduce the tendency of the material to come apart at grain bounderies. These alloys have great potential for increasing the efficiency of advanced energy conversion systems including turbine, Stirling, and diesel engines; recuperators for waste heat recovery; and solar energy storage systems. Based on these results, the conservation end-use programs, other DOE offices, and industry are now starting to fund the technology development and scale-up of these alloys for specific applications. The ECUT Program will complete its exploratory development of these alloys over the next two years.

Another ECUT high temperature materials development task has shown that the toughness (resistance to brittle fracture) of high temperature ceramics can be substantially improved by adding high strength ceramic whiskers to the ceramic matrix. Both the toughness and strength of $Al_2O_3$ can be more than doubled by using 20-30% SiC whiskers. Because of the importance of this development to adiabatic diesel engines, the further development of this ceramic composite material has been transferred to the Advanced Materials Development Program funded by the DOE Office of Vehicles and Engines R&D.

A second major ECUT materials work element focuses on lightweight materials. The increasing use of plastics in automobiles to reduce weight increases the amount of petroleum feed stock required for the plastics and also creates a problem with disposal of the plastic scrap. In a joint ECUT task with the Plastics Institute of America and several universities, hydrogen compatibilizers have been developed to join and mold into useful products the variety of plastics remaining from the auto shredder process. ECUT has now transferred responsibility for this development to the Office of Industrial Programs, which is funding the DOE demonstration of this technology in scrap yards across the country in cooperation with the Scrap Dealers Association.

The American Society of Mechanical Engineers[2] estimated in 1977 that as much as 11% of the energy consumption in the United States is used to overcome friction and wear losses. Because of the large energy saving potential in reducing friction and wear throughout the industrial and transportation energy sectors, a separate multidisciplinary ECUT Tribology Project was established in FY 1983. The major work elements are lubrication, tribological coatings, friction and wear testing, and design methodology. Research was started at the National Bureau of Standards on the lubricating qualities of base stock oils. This work shows for the first time which constituents of oils actually control friction. A second result has been the development of a simple test which predicts with reasonable accuracy how well a lubricating oil will work in an engine. This research may give the oil industry information leading to improved lubricants. Argonne National Laboratory is leading the work for ECUT on tribological coatings. The aim is to develop coatings for parts such as bearings, which will permit them to operate with less friction and longer life. During FY 1983 a workshop was held in which experts in the field agreed on priorities, and research was started. During the past year we also formed an Interagency Working Group on Tribology with representatives from DOD, NASA, DOC, and other DOE offices to coordinate planning and implementation of tribological research.

In summary, I have indicated the importance of ECUT projects to a range of conservation applications. Because of the close interface of ECUT with both basic research and applied programs, highly productive research can be accomplished rapidly. However, we have been able to work on only a small fraction of the high priority tasks that have been identified. With the management teams and working interfaces that have been firmly established over the past three years, ECUT projects are now in excellent position to effectively expand and capitalize on basic research results to increase the energy efficiency and productivity of the country.

## REFERENCES

[1] "Materials Research and Development. Report of the Energy Research Advisory Board to the United States Department of Energy." DOE/S-0027, November 1983 (p. 21).

[2] D. L. Wilcock and O. Pincus, "Energy Conservation through Tribology," American Society of Mechanical Engineers, New York, New York, 1977.

Mr. **Fuqua.** Thank you very much, Dr. Carlsmith.

Oak Ridge manages the DOE programs for refrigeration systems, appliances, and so forth. It is my understanding that that is proposed for termination in fiscal year 1985. Is that correct?

Dr. **Carlsmith.** That is what I understand, yes.

Mr. **Fuqua.** What kinds of things do you have that are not completed or that will be discontinued as a result of this funding termination?

Dr. **Carlsmith.** I mentioned several of them in my statement. They are such things as the use of mixed refrigerants to improve efficiencies of heat pumps; the use of higher efficiency commercial heating and cooling systems. One that I didn't mention in my statement that is an exciting possibility is the use of an electrically driven Stirling heat pump, which shows the promise of operating at much higher capacities at lower temperatures than are possible now. An additional one that I did mention is ground-coupled heat pumps, on which we are now already working.

Mr. **Fuqua.** Approximately how much money would it take to continue these programs you have just enumerated, just for fiscal year 1985?

Dr. **Carlsmith.** Our planning up to the present time has been based on approximately the same amount of funding that we have in fiscal year 1984, which is $3 million.

Mr. **Fuqua.** How many more years do we have left of testing and evaluation and research on these projects you are talking about?

Dr. **Carlsmith.** It varies depending on the individual projects. Some are scheduled to end within the next year or so. Others might continue as much as another 3 or 4 years.

Mr. **Fuqua.** But here is something in which we have been investing money for how many years?

Dr. **Carlsmith** The program has basically been going on since the mid-1970's.

Mr. **Fuqua.** So we have 10 years' investment, then.

Dr. **Carlsmith** Yes; in the last 2 or 3 years, we have been concentrating particularly on the longer range kinds of developments that industry is not able to fund from their own resources.

Mr. **Fuqua.** That was my next question. Do you think that the efforts at Oak Ridge in R&D, particularly in building systems, in building equipment, and these types of things we just discussed, are they being duplicated in the private sector? Are you doing something that they are doing or would be doing if you got out?

Dr. **Carlsmith** The things we are doing are certainly not being duplicated in the private sector. We have contacted all of the major firms in the private sector and understand well what they are doing.

The question of whether some of the work could potentially be picked up by the private sector is harder to answer, but the responses we get from industry are that the bulk of it would not be picked up if it were dropped by DOE.

Mr. **Fuqua.** Now, in the ceramics research program, that is going from $1.5 million to $7 million in 1985. Can we efficiently spend that much money or that much of an increase in 1 year in high-temperature materials?

Dr. **Carlsmith** Isn't it $6 million that is proposed? I am not certain.

Mr. **Fuqua**. Well, give or take a million. [Laughter.]

And that is in the transportation program for ceramics.

Dr. **Carlsmith** Oh, in the transportation? Are you speaking of the transportation work or the ECUT work?

Mr. **Fuqua**. The transportation work.

Dr. **Carlsmith** The transportation work. Yes, we have detailed plans in the transportation work for how that money would be spent, and it has been coordinated very thoroughly with the work that is being done in other related programs such as the work by NASA, work out in industry, and work in the Department of Defense.

Mr. **Fuqua**. So you think that much increase in 1 year, from $1.5 million to $7 million, can be adequately justified, then?

Dr. **Carlsmith** In fact we think that it is necessary for research of that magnitude to be undertaken if we are to hope to keep up with the foreign competition, particularly from Japan.

Mr. **Fuqua**. Does this include a demonstration project?

Dr. **Carlsmith** Not in the ceramics program, no. The programs that we are doing in the transportation area, feed into the other programs in transportation by Detroit Diesel Allison and by Garrett, which are designed to demonstrate turbine engines. But our program is not directly concerned with the demonstration.

Mr. **Fuqua**. I am not familiar with Allison, but the Garrett program, I know, is well along.

Dr. **Carlsmith** Yes; on the other hand, each review of that program has indicated that in order to meet the moving target of the competition, better ceramics need to be developed to go into the engine designs that are being produced out there.

Mr. **Fuqua**. Yes.

Dr. Lawrence, in the heat pump R&D activities in the DOE Office of Industrial Programs, are they adequately funded? Are they addressing the right priorities? Is there any additional work that you think should be done in this area?

Dr. **Lawrence**. There are two heat pump activities which I would like to address briefly in my answer if I could, Mr. Chairman, one in the industrial area which is looking specifically at industrial heat pumping and processes and product manufacture; and the other is in the residential area, in conservation.

If I might address the residential area first, we are recommending that the submission of $3 million be boosted up to $7 million in authorization and appropriations. I am personally familiar with the fact that the executives at DOE fought very hard with OMB just to get that $3 million in and were finally successful.

The reason is that we now have prototypes operating, several industrial entities. It is too early to tell which one is going to be the successful one in the marketplace. We are talking about a minimum of 40 million American homes as the market. We are talking about fuel savings of up to 50 percent, reduced fuel bills on the same order, 50 percent. It is an area which really needs significant enhancement.

We are still 5 to 7 years away from the marketplace, but we have to go from prototypes now through testing, multiple units, spare parts; put some real strong engineering talent in that area. That needs to go up to $7 million.

In the industrial area per se, there are several heat pump projects identifying things like taking waste heat and then generating steam through the heat pumping process; also organic vapor collection. Again we see a situation there where, due to OMB pressures, the submission has lowered those efforts because they thought that they were too much applied. I think that those efforts could play a great role in enhancing our industrial competitiveness. They ought to be put back to a minimum of last year's level and in fact enhanced a little if we are to accelerate those in the marketplace.

Mr. **Fuqua**. There are those that say that the improved climate, the economic climate, this rapid recovery that we are having and the Tax Act of 1981 are sufficient enough to stimulate business investment in productivity improving technologies, that the incentives are there, and we don't need the Government in these areas. Do you agree with that statement?

Dr. **Lawrence**. Mr. Chairman, my background and my career have been split almost exactly in half between Government service, when I was an executive back at ERDA, and then the gas industry, where I was a top executive in the Gas Research Institute, and then the last years where it has been strictly private industry.

I am familiar with the venture capital markets that exist today and how they are focused, and Government, and the effect of all of this legislation which you just mentioned.

I think what we are finding is that if we can show that something will have a payback in 2½ to 3½ years that will be significant, so that you can do the R&D, get the product to the marketplace, make the profit, and get the investors paid back in 2½ to 3½ years, there is plenty of venture capital available and tax incentives to cover that.

If you look at the 3½ to 10-year time period, there is really a vacuum there that can only be filled by the Government. Now, the Government is, especially under this administration, addressing 10 years out pretty heavily with investments. But that key place that really is absolutely essential to our national economic health, our future competitiveness, that 3½- to 10-year time period, is where there is real void, and if the Government doesn't pick it up, I can assure you that foreign competition will.

Mr. **Fuqua**. I am not sure whether it was Dr. Carlsmith, but maybe it was, maybe a year or so ago, in testifying here, that said that in the previous philosophy of the Department of Energy, if it were not in Sears Roebuck catalog in about 3 years, or a K-Mart store, that you were working on the wrong things; and now that has changed, and if it is in one of those places or a catalog within 3 years, you are working on the wrong things.

I don't want to blame you for it or give you credit for it if you want to deny it, but somebody from Oak Ridge—and it may have been you, I am not sure——said that.

Dr. **Carlsmith** I don't recall making that statement, but I would certainly endorse it. That is exactly what we find in investigating what can happen with developments that are made.

Mr. **Fuqua**. Mr. Brown, you indicated that in the direct strip steel casting there were four concepts being worked on, and you enumerated those companies that are looking at that. Does it look like any one of them is more favorable than the others? Or is it too early?

Mr. **Brown**. Mr. Chairman, my comment was that there were four different contracts addressing the feasibility of a variety of concepts. While Dr. Desai brought out the two that he felt were the most favorable, as a technical monitor for that program, I reached the same conclusions by looking over the work of the four of them.

Mr. **Fuqua**. That was going to be my next question: Did you agree with the conclusions that Dr. Desai came to?

Mr. **Brown**. I agree most heartily with Dr. Desai's conclusions.

Mr. **Fuqua**. Do you think it would be wise to embark on a pilot plant at this time, or would we be better off doing more research on two or more of the direct strip casting processes?

Mr. **Brown**. Speaking as a technical man, Mr. Chairman, I see a problem in not giving an adequate push to what I know has to be done sooner or later, and in my written presentation, which I request be incorporated in the record, I note that the Department of Energy Office of Industrial Programs is checking very closely to see the relationships between the pilot plant program as recently legislated and the phase II and following work which was called for by the original notice of program interest on the feasibility studies, to ensure that there is not a duplication, an overlap, of that effort.

The amount of funding which it is my understanding—here again, I am speaking as a technical supporter rather than an administrator—may fall short of what appears to be necessary. The amounts pursuant to the original notice of program interest may fall short of what appears to be necessary to pursue this to a point where it can be taken over by industry and become productive.

As for the amount that is necessary, here again speaking as a professional man, I performed a preliminary estimate on what I considered would be the cost of carrying through the pilot plant effort, and it is—I would prefer not to give the quantity—but suffice it to say that it is substantially more than the amount, the $30 million, given in the legislation.

This is one of the reasons why I stressed in my presentation my personal views on cooperation, not only technically but financially, between the industry and the Federal Government, in supporting work.

Mr. **Fuqua**. And let me commend you, too. You made one statement that really touched me because it is something we have been very interested in on this committee for some time, and that is expanding the role of our national labs to include industry and academia more than we have in the past. We hope to see more activity in that direction because I think it is in the national interest. We have some very excellent national labs, and we need to utilize them more fully in a broader capacity than we have in the past. We hope to see that trend beginning to develop. I know there are those in the administration that share that view, even Mr. Packard, who just recently conducted a look at the national labs.

So I am pleased to hear your comments about that, also.

Dr. Desai, do you think it would be wise to go ahead now with a pilot plant in the strip casting process, or with maybe the two processes that you alluded to in your statement, or should we do more—should this be put off for a while and let us continue to do more research and take a more critical look at all of these processes, including the two that you think are the more favorable?

Dr. DESAI. Based on the technical review we have done, we feel that there are a number of technical problems associated with the two technologies we are recommending. These are identified on pages 4 and 5 of my written testimony. We feel that those problems should be solved prior to any major undertaking such as a pilot plant.

Mr. FUQUA. How much longer do you think we would need to review this before you might have those problems solved, or is there a time frame?

Dr. DESAI. In my estimation, it will take approximately 1 to 2 years. At the same time, I should confess that if some of the companies have been privately working on it without our knowledge, it may take a somewhat shorter time. But the important thing is to try to resolve the problems which are listed here. Most of them are listed in our written testimony.

Mr. FUQUA. Well, let me ask you a question similar to the one I asked Dr. Lawrence a few minutes ago. With the tax incentives and so forth, is it not in the interest of the steel industry to pursue with their own private funds, or do we need Government participation in it?

Dr. DESAI. Mr. Chairman, personally, I feel that I am not qualified to comment on the subject because we carried out a technical evaluation and made technical recommendations, and we have not considered how the program should be funded.

Mr. FUQUA. Dr. Lawrence?

Dr. LAWRENCE. Yes, Mr. Chairman. I would be willing to address that. I am familiar with the thin-strip casting efforts.

I think that what we are looking at here is not only an opportunity for profit and competitiveness in the steel industry, but we are looking, also, at a degree of perceived risk which is excessive for the steel industry themselves to fund. I think this is a perfect example of the place where they are interested enough, where cost share could be expected. If the Government could pick up the risk, some of the perceived risk, and take that out of it through Government participation in this highly competent industrial conservation entity, you can see this be accelerated into the marketplace.

Mr. FUQUA. Mr. Brown?

Mr. BROWN. Mr. Chairman, I wish to excerpt a portion of the written presentation which has not been previously read. It is taken directly from the solicitation for cooperative agreement proposals put out in compliance with the legislation.

It says, and I quote,

> The pilot plant project is seen as a five-step effort: first, feasibility studies; second, process characterization, selection, and conceptual design; third, preliminary plant design; fourth, pilot plant final design and construction; five, pilot plant operation.
>
> Program entry at any of the first three steps is permitted if adequate information showing completion of the omitted steps is presented to DOE.

We have attempted to address in that manner and with our recheck, if you will, of the potential overlap of the phase II and following from the original feasibility studies and this legislation-mandated project, that we do not waste the Federal funding nor the amount of time which would be needed to bring these things to fruition.

Mr. FUQUA. Thank you.

Mrs. Schneider?

Mrs. SCHNEIDER. Dr. Lawrence, I would like to ask you a little bit about the heat pump. I was very much under the impression that the Japanese were already way ahead of us insofar as the development of the heat pump, and yet if I am following you correctly, I believe you said that it might be another 5 to 7 years or several years before we have a good heat pump. Is that correct?

Dr. LAWRENCE. Yes, Mrs. Schneider. I think I can clear that up, though, if I might.

The Japanese approach is one to get into the marketplace very quickly with technologies which might not be completely viable in the United States because our energy costs are still below much of the rest of the world.

Their approach is to take small internal combustion engines, much like you might have on your lawnmower or outboard motor, and to use gas or oil, then to drive the heat pump system with these engines.

For the United States application, they intend to start market penetration in the United States with these systems, but the other systems which DOE specifically is addressing, which are Stirling-activated heat pumps, using a very high efficiency, quiet Stirling engine, or a double absorption system, which is a special way of chemically getting a heat pump, those would be much more applicable to the American marketplace and more viable, when they are fully developed, and it is those that DOE would be addressing.

The Gas Research Institute is actually now chasing in the same direction as the Japanese. They are going after these small engines that we are more familiar with. But the things which would be of more substantial benefit and more applicability to the American situation are what we are talking about with the DOE programs.

Mrs. SCHNEIDER. Well, since we have to acknowledge the fact that we are living in a world economy, granted that the Japanese may be moving their products into the market, into the domestic market, much more rapidly to satisfy their own national needs, but what about in terms of the rest of the international market? Are we going to continue to see the Japanese exporting their—as you are politely saying—not quite perfect yet products into Europe and into other parts of the world? And are we going to continue to lag behind insofar as the international market is concerned?

Dr. LAWRENCE. I think you are absolutely correct, that that is exactly what the Japanese are going to do. They understand the worldwide market better than any other country, and that is precisely their approach. They have something which they think they can make a first market penetration with worldwide in this equipment. The United States, thanks to some of the prior Government funding, is in the position with some of these advanced technologies really to leapfrog the Japanese products, but we must get through a period now where we go from prototype to really a viable preproduction type product, and that is what we are really after in these advanced technologies. It would be more attractive.

Mrs. **Schneider**. You are from New York.

Dr. **Lawrence**. Yes, ma'am.

Mrs. **Schneider**. I would like to know if there is some kind of conspiracy going on insofar as technology transfer is concerned, because being one who is sensitive to the manufacturing, for example, in New England and the Northeast/Midwest part of the country, but particularly in New England where we have older facilities; we have many factories that are closing down. Many of these factories might survive if they had some of the technology of changing waste heat into steam, or if they had some of the other technologies that might enable them to reduce their energy overhead.

They don't have that technology nearly as quickly as I think that they should, and as a result, they are moving to parts of the country where the energy costs are a lot cheaper. How do we protect the Northeast? You will excuse me, my colleagues from the other parts of the country here.

Mr. **Skeen**. We'll help you with your paranoia. [Laughter.]

Dr. **Lawrence**. I can relate to exactly what you said very deeply, Mrs. Schneider. As you know, we are from Albany, NY, which is considered New England, and we really distinguish ourselves very much from New York City, which is 200 miles away to the south, and we face exactly the kinds of problems that you are describing in our own particular area, with lots of people being laid off from manufacturing facilities which are somewhat outdated because of this problem.

I think it goes back—if I can try to address it simplistically in a very short period of time—it goes back to the statement that I made a little bit ago, that this 3½- to 10-year time period is the time period in which the things that have been brought to prototype by the ERDA and DOE need to be fully developed and implemented into the marketplace. It is the time period where venture capital absolutely is not interested.

Venture capital also is not that interested in mechanical equipment, because it is not a real high flier that is going to be the $100 million in 2 years kind of thing, like the computer industry. It is the area with very high value added, very high employment value, high balance of trade value, and it is the area where foreign governments are focusing a lot of their capital, and we really just have to have the Government be aware that they must participate in this area if we are going to be successful in it in the United States.

Mrs. **Schneider**. And how do you suggest that we get the Government to do that?

Dr. **Lawrence**. I think, Mrs. Schneider, from what we have seen of you and your tenure in the Congress, that people like you being aware and driving these kinds of issues gives us a good chance of that happening.

Mrs. **Schneider**. Ah, shall I say flattery will get you everywhere or what? [Laughter.]

I thank you, ~~but~~ boy, I sure could use some teamwork, I will tell you.

I had another question of Dr. Desai. Insofar as the steel industry is concerned, do you think that it is good Federal policy to encourage the steel industry to modernize, or should we essentially go with the flow and allow the production of steel outside of our borders to continue?

Dr. DESAI. Again, as I pointed out, we have not studied those kinds of questions, but I will give you my personal opinion. I feel that the steel industry can use some help in developing these kinds of processes as far as dealing with the competition is concerned.

Mrs. SCHNEIDER. And do you think that the help that you are recommending, Federal assistance, do you think it should be targeted toward old plants or to the establishment of new, more fuel-sufficient and all around more efficient facilities?

Dr. DESAI. I did not recommend any Federal help in my written or oral presentation. All we are saying is, these processes have definite economic and technical potentials, and they ought to be developed in this country.

Mrs. SCHNEIDER. All right.

Now I have a question for the entire panel. Any one of you who chooses to answer, you are welcome to. As you know, we are currently observing a Iraq-Iran conflict. There is much question as to the future actions on the Straits of Hormuz.

I think that you also are all very much aware of our continued reliance on foreign oil. If, let us say, the straits were closed, barring any other ideas or actions that the administration might take, how quickly could your different companies mobilize to shorten that span of time from perhaps 3-1/2 to 10 years or 2 to 5 years, to immediately bring onto the market technologies that could allow us to stretch those domestic supplies that we already have?

If there were a crisis and you had to react, how quickly could you put on the market the goods that would save us that precious oil?

Dr. CARLSMITH I will say for my part, on the kinds of things that I was talking about, it is going to take some time to develop them, the high-temperature materials, for instance, and the ceramics.

I think the work needs to proceed at a timely pace, which is that we need to take advantage of what we know and then go on from there to develop materials so that they can be used to improve transportation and industry's efficiency.

I don't think that it would be realistic to say that those developments could be speeded up in such a way as to take care of the kind of emergency that you are talking about.

On the other hand, there are lots of things that conservation can do even in a short-term emergency in taking advantage of technologies that already have been developed, and most of those kinds of things have not been discussed here today, but I think our emergency planning should recognize and look to how those things can be used in an emergency that is not at all unlikely in the next few years.

Mrs. SCHNEIDER. Yes, Dr. Lawrence? Do you want to respond to that?

Dr. LAWRENCE. Yes, Mrs. Schneider.

Briefly, without mincing words, I think that what we in the conservation equipment, if you will, industry have faced in the past 3 years has been a debilitating and survival experience.

By the same token, those of us who have been fortunate enough to survive with some of our teams still intact are in positions where, if such a crisis should occur, if there was some instant market demand with some Federal recognition and help, I think we could see substantial acceleration from where we are into where we are presently projecting. There are a number of things that, in that environment, could be brought out to bear.

Mrs. SCHNEIDER. All right. Thank you.

Yes?

Mr. BROWN. Mrs. Schneider, there is an apparent dichotomy in my mind as to the role of the Idaho National Engineering Lab, primarily because it goes back to when it was the National Reactor Testing Station. We have had two fairly distinct categories of activity ongoing there. One, of course, was nuclear energy per se. The other one was our more recent role in technical monitoring and other support of industrial energy conservation programs, which I am inclined to view as making sure that the work is done on the outside and that, to the extent that it appeared to be financially and otherwise feasible, was put in place by those who had developed it, and to the extent that the Federal Establishment and the national labs could so do, make sure that the technology was transferred for general availability.

As I see our role there, we are dealing with an accomplished fact rather than, in the case of Dr. Carlsmith at Oak Ridge, where their in-house work is probably of substantial importance as compared with the outside work.

I have to say that our major contribution has been in the program administration and monitoring as far as the energy initiatives are concerned.

Dr. Diehl, do you have any problem with that statement?

Mr. DIEHL. No.

Mr. BROWN. Thank you.

Mrs. SCHNEIDER. Can I assume that all of you are supportive of the extension of the energy tax credit?

[No response.]

Mrs. SCHNEIDER. Well, let us hope that we see some lobbying taking place to pass our chairman's initiative here to extend tax credits.

The only other point that I would like to leave—I know that witnesses always feel that they have to leave us with information. I would like to leave you with something, too. In addition to your lobbying effort to see to it that those energy tax credits are extended, I would also like to see a greater advertising effort, perhaps. We know General Electric does a great deal of terrific advertising, and some of the other companies might not have the budgets for that sort of thing, but I would certainly think that one of the vacuums that I find is that my constituents are not aware of the technology that you have available until it is advertised or it reaches some segment of the market.

So if we can sharpen up on our technology transfer and information strategy, I think we will do a whole lot better in making this country a little more energy selfsecure.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you.

Mr. Lewis?

Mr. **Lewis**. Thank you, Mr. Chairman.

Dr. Desai or Mr. Brown, how excited is the steel industry over your two methods of rolling steel at this point?

Mr. **Brown**. Let me state the question as I understood it from you, Mr. Lewis. You want to know how excited, how enthusiastic, the steel industry is concerning these approaches.

Mr. **Lewis**. That is true, both of them.

Mr. **Brown**. I feel that there is a substantial amount of interest along these lines, although, as the old saying goes, it is hard to tell who is sleeping with whom in a corporate sense without a program.

As an example, last summer we were given—we, the technical monitors of the thin-strip feasibility program—were told by Battelle Columbus Laboratory personnel that they concurrently had an ongoing effort with National Steel Co., and the details, of course, were withheld from us, but the impression that we got was that the two programs would feed, one upon the other, toward a common goal to get this technology transferred, to get it developed, to get it into use where the users of it could be internationally competitive.

Speaking from the same program but in a different location, when we as technical monitors were discussing with the program people at the Massachusetts Institute of Technology what their plans might be pursuant to the stated contract requirements, they, MIT, made it very clear that they were currently seeking an industrial connection with which they could pursue follow-on work.

Our contacts with Westinghouse Co. and their subcontractor, United States Steel, on that same trip, for the same purposes, came up with approximately the same information: United States Steel was very much excited about the possibilities of regaining a competitive edge through a development of this transfer; an aside to that particular source came from an earlier conversation during work on another program with United States Steel, when I asked, "What are you people doing, to your knowledge, in the field of continuous casting to get down to where we belong, the objectives of thin strip production?" and the answer came out—and I will paraphrase—we currently produce 4-inch thick slabs by continuous casting methods; we are now developing a method which will take us down to perhaps 1-inch thickness, from which we can more conveniently roll the necessary strip and sheet.

Yet another illustration is a company called Southwire, of Carrollton, Ga. I have had a number of conversations with them. They are marketing equipment for continuous casting of the nonferrous metals, aluminum and copper alloys, and they stated that they had successfully, on a commercial scale, cast smaller than 4-inch sections and felt that they, too, could come down to 1 inch. Now, they, however, are a steel manufacturing equipment company rather than a steel manufacturing company.

These to me are indications that they are ready to seize this opportunity and run with it if they are given adequate encouragement.

Now, admittedly, my version of encouragement, as stated in my written presentation, is that we insist upon them making a substantial contribution in funds, in kind, in facilities, what have you, because it is plain that this is to their benefit first, although it is then to our national benefit.

I feel that, yes, we have a more than adequate amount of enthusiasm on the part of the steel companies for this technology.

Mr. **Lewis**. It sure would seem to me that profit would certainly be an encouragement to the steel companies in order to pursue this further and also invest their own funds as well.

Mr. **Brown**. Agreed.

Mr. **Lewis**. Dr. Desai.

Dr. **Desai**. Yes; I would say the steel industry would be quite excited about the two processes we are recommending. Some of the top steel companies, including U.S. Steel, Bethlehem Steel, Allegheny, National, have done work or are currently doing work on these two processes, but because of funding or other reasons, the processes were either dropped or the work is being done at a very low level.

So I would say, in general, that the steel industry would be very excited to commercialize these processes.

If I may go back to an earlier question which was asked of me by Mr. Fuqua regarding how long it will take to develop these processes, the development and pilot plant work can be done faster if more money is made available. I cited a period of 1 to 2 years, and I am saying that it can be done faster if more money is made available.

Mr. **Lewis**. I just get concerned. It appears that it is one-sided and that the Federal Government is funding a program which seems to be an adequate one to bail out the steel companies, reduce their costs, increase their profit margin and get them more competitive than they have been for years, but they are sitting back and allowing the Federal Government to do this, along with funding you, to have you assist them to come out of the doldrums, and it just doesn't set very well with me.

Yes, sir.

Mr. **Brown**. Mr. Lewis, if I may, the question that you have posed was addressed very specifically in the solicitation for cooperative agreement proposals. The language of it, as nearly as I can cite it, is that up to twice the amount of Federal support shall be repaid by users, both direct and under license, from the profits of this technology.

We sense your apprehension. We share the apprehension, also. We therefore attempted to put into the solicitation language, and will put into the contract, such words as will attempt to ensure that the taxpayers at large share in this investment, and that it shall be an investment, not an outright donation.

Mr. **Lewis**. That makes me feel much better.

Mr. **Brown**. If I may add one other thing, it was not clear from my verbal presentation and perhaps would not be in my written presentation, either, but the information concerning the DOE-initiated thin-casting concept went out to the recipients of the original solicitation as an amendment in January. We do not yet have a reading from the industry on that to determine what their reaction is to this concept.

Mr. **Lewis**. I am sorry. Go ahead.

Mr. **Brown**. We do not yet, since January, have a real reading on how the industry has received this really innovative concept which attempts to bypass some of the problems in extrapolating conventional thin-strip casting technology to the very thin sections.

Mr. **Lewis**. I see. Thank you, Mr. Brown.

Madam Chairman, I have one question for Dr. Carlsmith.

Mrs. **Schneider** [as acting chairman]. Would the gentleman mind yielding to Mr. Nelson, and then we can come back and you can have all the time you would like. Mr. Nelson has to run to a caucus.

Mr. **Lewis**. Well, I will yield to Mr. Nelson. I have to make an emergency phone call.

Mrs. **Schneider**. You do? Will you be back to ask the other part of the question?

Mr. **Lewis**. I will try.

Mrs. **Schneider**. All right. Thank you.

Mr. Nelson?

Mr. **Nelson**. I appreciate the gentleman for yielding. The bells are ringing and I need to go to that, and I just wanted to make a comment, Madam Chairman, as a follow up to your statement about troubles in the Persian Gulf region.

I have said since 1979 that surely there would be a repetition in some form of the events that we witnessed in 1973 and again in 1979, and it looks like the activities that are chronicled on the front pages of the newspapers daily now would indicate that that is likely to come, and in what form I don't know or for what reason I don't know, but surely another disruption is going to occur at some point in the future.

Having said that, I think that the subject of this hearing today, conservation and solar energy, is of enormous importance as we try to handle these disruptions in the future. The fact of energy conservation through new technology, though new efficiency in industrial processes, in utilizing waste heat, is absolutely essential.

The question of tapping God's constant source of energy that He provides to us each day from the Sun is absolutely essential for the future.

I appreciate Chairman Fuqua setting up this hearing. I have a major solar energy center located in my congressional district at Cape Canaveral, and I am aware of the research that they have and some of the breakthroughs that they have in solar energy research there, and so it is my pleasure, Madam Chairman, that I could give this little editorial before I have to dash off to this meeting indicated by those three bells up there.

Thank you very much.

Mrs. **Schneider**. If there are no other comments that the panelists would like to leave us with, then we will adjourn to the next panel. Any other comments?

[No response.]

I thank you very much for your testimony. It was most enlightening, and we appreciate your assistance in our decisionmaking process.

I now would like to call upon the next panel, the solar energy panel, with Dr. Harry Zwibel, Dr. Donald Feucht, John Mattimoe, and Dr. Charles Gay.

Congressman Joe Skeen from New Mexico regretted that he had to run out for a moment. He will be back with us shortly, but I would like to take this opportunity to introduce John Mattimoe, general manager of the Sacramento Municipal Utility District. Mr. Mattimoe, why don't you begin with your testimony?

## STATEMENT OF JOHN J. MATTIMOE, GENERAL MANAGER, SACRAMENTO MUNICIPAL UTILITY DISTRICT

Mr. MATTIMOE. Thank you, Madam Chairman.

Madam Chairman and members of the subcommittee, I request that my written testimony be introduced into the record, and I will summarize that testimony in my remarks today.

I appreciate the opportunity to testify before you. For the past 3 years, this committee has been instrumental in obtaining support from Congress for the Sacramento Municipal Utility District—more commonly known as SMUD—in its innovative plan to construct the world's first utility-owned photovoltaic powerplant. Today I would like to inform you of the status of that project and discuss with you our plans for its future direction.

Three years ago, my predecessor, William Walbridge, testified before you to explain a novel plan for the development of a 100-megawatt photovoltaic powerplant which the district was proposing. The essence of the district's plan is that the Federal Government advances to the project the difference between the cost of the early stages of the project and the value of the generation capacity constructed.

In the later stages of the project, as the cost of photovoltaics decreases, the district returns to the Government the funds advanced in the early stages.

The initial SMUD proposal was greeted with skepticism. The district was told that it would be impossible to construct a 1-megawatt system for $12 million and that the tracking panel design proposed for the first stage was poor because it could never be cost effective.

I am glad to state this morning what many of you already know: The first stage of the project is now nearing completion, on schedule, and at a cost well below the original budget. Furthermore, the concept of tracking PV systems is now well established in the DOE program and has been used by developers of other photovoltaic systems as well.

The phase I system is a landmark which is showing utilities and the PV industry that photovoltaic power has a place in America's energy future.

Madam Chairman, we are planning the dedication of our first megawatt phase of the project on Friday, July 13, of this year, and we would be delighted if you or other members of the committee would attend.

While phase I is rapidly nearing successful completion, phase II is also well underway. Whereas phase I was configured to confirm design concepts and establish that a relatively low-cost megawatt system could be constructed, phase II is being developed as a PV equipment test bed which will establish the specifications and the suppliers needed in larger systems of the future.

In phase II we expect to have as many as seven photovoltaic manufacturers involved, providing a range of cell technologies including single crystal silicon, ribbon, and amorphous films.

As in phase I, the second phase of this project has also been a leader in the development of large-scale photovoltaic systems. We currently expect that the system costs for phase II will be below the record-setting levels of phase I. The phase II test bed will be unique among the world's photovoltaic research systems. In one location, we will have as many as seven systems, designed to common performance standards, representing the full range of current and advanced technology photovoltaic devices. We even plan to include a sunlight concentrating system for evaluation.

From the phase I and II results, we at the district are confident that the photovoltaic systems will become a significant part of our generation mix by the end of this decade. We now project that this first 100-megawatt project can be built in 5 rather than the 10 phases originally planned.

The table presented in the written testimony presents the revised project plan for the full 100-megawatt powerplant. You will note that the table shows that the Federal investment in the project will end with phase III. This is a critical event for our project. Once the Government's commitment to our project is complete, the most significant strength of the project concept becomes a reality.

The district will have needed assurances to enter into long-term agreements with photovoltaic equipment suppliers for very large quantities, even if the initial deliveries are not cost effective for the district.

For system design reasons, we have established phase III as a 5-megawatt building block which could be replicated to build larger plants in the future. Once we receive full commitment from Congress, our strategy will be to enter into agreements for procurement of at least 30 megawatts of photovoltaic panels. This includes 6 megawatts for phase III and 24 megawatts for phase IV.

During recent discussions with key photovoltaic industry representatives, we were told that such an opportunity could be a major driving force in justifying investments in new plants and technology needed to bring the prices down.

Our experiences in phases I and II give us confidence that a 5-megawatt building block powerplant can be installed for $40 million by 1986 and that four such blocks can be installed for $80 million by 1989.

To achieve these projections, we need to purchase photovoltaic panels at $4 for phase III and $2 for phase IV.

The Federal Government appropriations for each phase are shown on the table. We are proposing that the $40 million total cost of phase III be equally shared by the district and the Federal Government. Because $1.5 million was appropriated in fiscal year 1984, the remaining requirement is $18.5 million. The most expeditious approach is, of course, to appropriate the funds for fiscal year 1985.

We must receive a clear and binding commitment to proceed so that we can provide guarantees to vendors that we will buy up to 30 megawatts when our price targets can be met.

With your support, we will be able to challenge the photovoltaic industry to produce a product which will make photovoltaic power costs competitive within the utility industry. As the table indicates, the combinations of phases III and IV will inject up to $120 million into the photovoltaic industry, all for an additional Federal investment of $18.5 million.

I would suspect that this 6-to-1 cost-sharing approach is unusual, but what is even more appealing is that it is significantly less expensive to the taxpayer than support of this project through existing tax incentives. The district's low cost of funds not only makes possible our interest in direct purchase of a large-scale photovoltaic system; it makes it possible to propose such a purchase in a period after 1985, when the continuation of solar energy tax credits is in doubt.

As a result of the uncertainty surrounding the extension of these credits—an issue which I am sure you are deeply concerned about—the district may well be unique in its ability and willingness to contract for a large-scale solar energy powerplant of any type. We therefore see it in the national interest, as well as in our own, to propose continuation of this project along the lines I have discussed.

From our discussions with the photovoltaic industry and with other utilities, we have concluded that SMUD, through its commitment to purchase the first utility-owned photovoltaic powerplant, could establish the photovoltaic industry as a self-sustaining supplier to the utility sector.

Indeed, other utilities are showing great interest in our project. For example, last fall Florida Power and Light purchased the phase I test array, a 10-kilowatt array, for comparative testing in Florida.

In summary, this project, which has received such broad support from the photovoltaic industry, from other utilities, from the people of California, and from you here in Congress, is now at a crossroad. By moving forward, the Government's contribution will be complete and a firm challenge will be laid down to the U.S. photovoltaic industry.

Madam Chairman, I believe we have proven that our project concept is viable, that our project team is capable of accomplishing unique and difficult plans in a manner which justifies the trust given us by Congress and the people of Sacramento. The District has welcomed the opportunity to be at the forefront of utility involvement in photovoltaics. We look forward to a continuation of that involvement.

This concludes my testimony. Thank you for the opportunity to appear.

[The prepared statement of Mr. Mattimoe follows:]

Statement of
John J. Mattimoe, General Manager
Sacramento Municipal Utility District
Before the Subcommittee on
Energy Development and Applications
February 29, 1984

Mr. Chairman, members of the Subcommittee, I appreciate the opportunity to testify before you this morning. For the past 3 years this Committee has been instrumental in obtaining support from Congress for the Sacramento Municipal Utility District's (SMUD) innovative plan to construct the world's first utility-owned photovoltaic powerplant. Today I would like to inform you of the status of that project and discuss with you our plans for its future direction.

Three years ago, my predecessor, William Walbridge, testified before you to explain a novel plan for development of a 100-MW photovoltaic powerplant which the District was proposing. The plan involved a 10-phase project, starting in 1982, which would result in the construction of the 100-MW plant over 12 years. The District proposed that the initial stage of the project would be 1 MW in size and would be constructed using fiscal 1982 funds for a total cost of $12M; of the $12M, the Federal contribution would be $6.8M.

The essence of the District's plan is that the federal government advances to the project the difference between the cost of the early stages of the project and the value of the generation capacity constructed. In the later stages of the project, as the cost of photovoltaics decreases, the District returns to the government the funds advanced in the early stages.

The initial SMUD proposal was greeted with skepticism. The District was told that it would be impossible to construct a megawatt system for $12M and that the tracking panel design proposed for the first stage was poor because it could never be cost effective.

I am glad to state this morning what many of you already know. The first stage of the project is now nearing completion on schedule and at a cost well below the original budget. Furthermore, the concept of tracking PV systems is now well established in the DOE program and has been used by developers of other PV systems as well. The phase I system is a landmark which is showing utilities and the PV industry that PV power has a place in America's energy future.

I would like to identify a number of specific contributions of the phase I effort:

1. As expected, our large purchase of PV modules has been a catalyst to establish new price milestones and create a market environment where other large PV projects can go forward.
2. We have developed a system design which meets the conservative requirements which are typical of utility practice. Our structure is designed consistent with existing codes to operate for a minimum of 30 years. This was done while achieving the lowest unit cost of any large PV project ever built.
3. The tracking array design in our system was developed, tested, installed, and brought to a condition of commercial readiness all within phase I. We believe the design will be of general use for our future phases and for most other utility applications as well.
4. We motivated the development of a high efficiency, high reliability power conditioning unit to convert direct current power to alternating current at the megawatt scale.

5. We have established and tested new techniques to protect the system from ground fault failures and ensure safety of operation and maintenance personnel. In creating the 1-MW phase I system, we have faced and solved the many practical problems which are generally not addressed by research programs but which must be solved before commercial use of a technology is possible.
6. Finally, we carried out phase I in the open arena of public visibility and review by the DOE and experts from government laboratories. At each step, programmatic direction was thoroughly evaluated and justified on technical grounds. I can firmly state that our technical approach represents a consensus of the knowledge within the United States today.

While phase I is rapidly nearing a successful completion, phase II is also well underway. Whereas phase I was configured to confirm design concepts and establish that a relatively low-cost megawatt system could be constructed, phase II is being developed as a PV equipment test-bed which will establish the specifications and suppliers needed in larger systems of the future. In phase II we expect to have as many as seven PV manufacturers involved, providing a range of cell technologies including single crystal silicon, ribbon, and amorphous films. Rather than simply accepting existing off-the-shelf modules, as was done in phase I, we are now specifying botn performance and physical parameters suitable for utility use. Through our phase II specifications we are beginning to set standards within the industry for what I shall call "utility-qualified PV panels." We have been pleased with the response of the PV industry to phase II, and we fully expect that it will be completed within budget during 1985.

As in phase I, this second phase of the project has also been a leader in the development of large-scale PV systems. We currently expect that the system costs for phase II will be below the record-setting levels of phase I. The phase II test-bed will be unique among the world's photovoltaic research systems. In one location we will have as many as seven systems, designed to common performance standards, representing the full range of current and advanced technology PV devices. We even plan to include a sunlight concentrating system for evaluation. The ability to obtain accurate comparative data will be unmatched by any system anywhere.

From the phase I and II results, we at the District are confident that photovoltaic systems will become a significant part of our generation mix by the end of this decade. We now project that this first 100-MW project can be built in five, rather than the ten phases originally planned. The table in the written testimony presents the revised project plan for the full 100-MW powerplant.

You will note that the table shows that the federal investment in the project will end with phase III. This is a critical event for our project. Once the government's commitment to the project is complete, the most significant strength of our project concept becomes a reality. The District will have the needed assurances to enter into long term agreements with PV equipment suppliers for very large quantities, even if the initial deliveries are not cost-effective for the District.

For system design reasons, we have established phase III as a 5-MW building block which could be replicated to build larger plants in the future. Once we receive full commitment from Congress, our strategy will be to enter into agreements for procurement of at least 30 MW of PV panels. As shown in the table, this includes 6 MW for phase III and 24 MW for phase IV.

During recent discussions with key PV industry representatives, we were told that such an opportunity could be a major driving force in justifying investments in new plants and technology needed to bring prices down.

Given the dynamic nature of the PV industry, we recognize that terms and conditions for such agreements will need to be flexible, particularly in the later years. However, the agreements will be more than letters of intent. They will be purchase orders giving the District the right to obtain the equipment needed for both phases III and IV.

The table shows our estimates of overall system price for the five project phases. Our experience in phases I and II gives us confidence that a 5-MW building block powerplant can be installed for $40M by 1986 and that four such blocks can be installed for $80M by 1989. To achieve these projections, we will need to purchase PV panels at $4 for phase III and $2 for phase IV.

The table also shows the federal government appropriations for each phase. We are proposing that the $40M total cost of phase III be equally shared by the District and the federal government. Because $1.5M was appropriated in fiscal 1984, the remaining requirement is $18.5M. The most expeditious approach is, of course, to appropriate the funds for fiscal 1985.

In this era of deficits, however, the District recognizes that such a sum may not be feasible within the context of other energy development priorities and the budget. Since the majority of cash will not be spent until 1986, we could consider alternatives to immediate funding. We must, however, receive a clear and binding commitment to proceed so that we can provide guarantees to vendors that we will buy up to 30 MW when our price targets can be met.

With your support, we will be able to challenge the PV industry to produce a product which will make PV power cost competitive within the utility industry. As the table indicates, the combination of phases III and IV will inject up to $120M into the PV industry, all for an additional federal investment of $18.5M. I would suspect that this 6 to 1 cost-sharing approach is unusual; but what is even more appealing is that it is significantly less expensive to the taxpayer than support of this project through existing tax incentives. The District's low cost of funds not only makes possible our interest in direct purchase of a large-scale PV system, it makes it possible to propose such a purchase in a period, after 1985 when the continuation of the solar energy tax credits is in doubt. As a result of the uncertainty surrounding the extension of these credits -- an issue, Mr. Chairman, about which I understand you are deeply concerned -- the District may well be unique in its ability and willingness to contract for a large-scale solar energy powerplant of any type. We, therefore, see it in the national interest as well as in our own to propose continuation of this project along the lines I have discussed.

From our discussions with the photovoltaic industry and with other utilities, we have concluded that the successful completion of phase IV at the projected $4/watt would establish photovoltaic systems as a viable option for power generation by a large number of southern and western utilities. Many of my companion municipal utilities would find photovoltaics at $4/watt competitive with gas turbines for peaking applications. Therefore, it is quite possible that SMUD, through its commitment to purchase the first utility-owned PV powerplant, could establish the PV industry as a self-sustaining supplier to the utility sector. Indeed, other utilities are showing great interest in our project. For example, last fall Florida Power and Light purchased the phase I test array for comparative testing in Florida.

In summary, this project, which has received such broad support from the PV industry, from other utilities, from the people of California, and from you here in Congress, is now at a crossroad. By moving forward, the government's contribution will be complete and a firm challenge will be laid down to the U.S. PV industry. We fully expect this challenge to be met and that we will have a new source of cost-competitive electrical energy by 1990.

Mr. Chairman, I believe we have proven that our project concept is viable and that our project team is capable of accomplishing unique and difficult plans in a manner which justifies the trust given us by Congress and the people of Sacramento. The District has welcomed the opportunity to be at the forefront of utility involvement in photovoltaics; we look forward to a continuation of that involvement.

This concludes my formal testimony, I would be pleased to answer any questions the Committee may have. Thank you for the opportunity to appear today.

100-Megawatt Photovoltaic Powerplant
Installation Plan

| Phase | Construction Year | Size | | Installed Costs | | Government Share[a] ($M) |
|---|---|---|---|---|---|---|
| | | ($MW_{DC}$) | ($MW_{AC}$) | ($\$/W_{AC}$) | ($M) | |
| I | 1983 | 1.2 | 1 | 11.5 | 11.5 | 6.8 (FY 82) |
| II | 1984 | 1.2 | 1 | 10.4 | 10.4 | 6.8 (FY 83) |
| III | 1986 | 6.0 | 5 | 8.0 | 40.0 | 1.5 (FY 84) |
| | | | | | | 18.5 (FY 85)[b] |
| IV | 1989 | 24.0 | 20 | 4.0 | 80.0 | 0 |
| V | 1992 | 87.6 | 73 | 2.7 | 195.4 | 0 |
| | | | 100 | | | |

[a] Repayments not shown
[b] Proposed for consideration

Mrs. **Schneider**. Thank you very much.

Now I would like to call on my colleague from New Mexico, Congressman Joe Skeen, to introduce Dr. Zwibel.

Mr. **Skeen**. Thank you, Madam Chairman. I just want to congratulate you, first of all, for your ascension to the chair here. It took a Democratic caucus to do it. [Laughter.]

But there couldn't be a more capable person handling the chair. We kid each other an awful lot. I am not a member of this committee, by the way, and I do want to thank you, right at the outset, for the extension of the courtesy to me, because I wanted to come over and say a few good words for Harry Zwibel, who has been a long-time friend and a person that I have relied on in great part for consultation on solar energy matters. He has got a project going in New Mexico that we are extremely proud of, but I think it primarily demonstrates his great qualifications as a manager, because these days it isn't just enough to be a physicist, which he is, and with all the experience in the world, you have got to get out and sell these programs, and one of the toughest selling jobs has to be here in Congress for the kind of support that is necessary to keep this technology going.

New Mexico, I think, is dedicated to the development of all kinds of energy technologies, and particularly these dealing with solar energy. Harry has done an outstanding job at New Mexico State University, and we are very proud of it.

We are glad to have you up here, Harry, and I do want to say again that I do appreciate the opportunity to come over and say a few good words for you, Harry, and then I can cuss you out later. [Laughter.]

Thank you, Madam Chairman.

Dr. **Zwibel**. Thank you.

## STATEMENT OF DR. HARRY S. ZWIBEL, DIRECTOR, NEW MEXICO SOLAR ENERGY INSTITUTE

Dr. **Zwibel**. Madam Chairwoman, Mr. Skeen, members of the subcommittee, I thank you for an opportunity to give my views.

I will focus my presentation on the Department of Energy's photovoltaic system engineering and standards and test and evaluation program. In particular, I will address the three residential experiment stations.

If I may leap ahead to the conclusion, my recommendation is that the Department of Energy maintain a balanced program that includes systems research, research on distributed systems, experimentation on small-scale systems and operation of the residential experiment stations.

In the following, I will discuss the needs for systems research and development, which includes small-scale systems experiments, the residential experiment stations in general, and the southwest resident experiment station in particular.

By systems research and development, I mean all the steps involved in advancing the state of the art in complete, full-scale photovoltaic systems. It involves systems analysis, design, assembly, test, and evaluation.

In the systems R&D process, complex systems do not go directly from the laboratory to the field. Even though individual components have been tested and debugged, the interplay between these components and the real world invariably uncovers problems. For this reason, prototypes must first be tested and evaluated in an experimental setting.

Systems experiments can reveal catastrophic failures. For example, initial residential systems photovoltaic experiments at the RES's uncovered, quite unexpectedly, I might add, failures in the DC to AC inverters. Systems experiments also provide a technology data base. This is a key element in the transfer of systems research results. Such technology transfer must take place if photovoltaic systems are to find widespread acceptance by designers, planners, builders, and potential users.

I would now like to discuss the residential experiment stations. There are three of them. The Northeast RES is located in Concord, MA, and operated by the Massachusetts Institute of Technology. The Southeast RES is located in Cape Canaveral, FA, operated by the Florida Solar Energy Center for the University of Central Florida, and the Southwest RES, which is located in Las Cruces, NM, operated by the New Mexico Solar Energy Institute for the New Mexico State University.

The RES's were established for the residential photovoltaic program and currently have a major role in that program. In addition, their responsibilities have been broadened to include nonresidential photovoltaic experiments.

The RES's cover extreme climatic regions of the country. They are located in States that strongly support solar energy research, and they are affiliated with major universities. Furthermore, each RES is fully established with state-of-the-art data acquisition equipment, support facilities, full-scale residential prototypes, for a total of 17, and specialized test structures.

Each has an experienced, qualified, enthusiastic staff that conducts a wide variety of specialized experiments. The RES's are a unique source of knowledge on the operation of utility interactive photovoltaic systems.

Finally—and I would like to stress this point—the RES's are extremely cost effective to operate.

The following issues are of particular importance in the RES program: system installation for both new and retrofit construction; system safety and reliability; design guides and methods; and utility interface concerns.

Rooftop photovoltaic system installation will involve a variety of trade jurisdictions, including workers in the current solar industry, electricians, roofers, and carpenters. Finding an acceptable division of labor will require a cooperative effort among the concerned groups. The RES's are ideally suited for the hands-on education that would be required.

Buyers need to be assured that the system will operate safely and reliably. Recollect early solar hot water failures that still cast a long, dark shadow over solar. With the photovoltaic program, however, the RES's are providing an unbiased data base for both component level and system level performance, reliability, and durability.

Problems and concerns of utilities must be identified and addressed if interconnection is not to be a major barrier to market penetration of residential photovoltaic systems. The experimental and analytical work in this area is, and will continue to be, closely coordinated with the regional utilities.

I would now like to discuss the Southwest RES. The Southwest RES employs a professional on-site staff of 5, with the support of 14 New Mexico State University engineering students. They form a team that collectively has more than 18 man-years of photovoltaic systems experience.

The experiment station is situated on three choice acres of university land that is given without charge to the Southwest RES. The photovoltaic center is a 3,000-square-foot building that houses the offices, workshop, data acquisition and computer room, and visitor center.

Funding for this building was provided by the State of New Mexico under the energy research and development program. I would like to emphasize that the capital equipment—such as computers, data sensors, shop equipment, and nine full-scale experimental photovoltaic systems—is all paid for and in use.

Continued operation of the Southwest RES—in fact, of all the RES—is cost-effective because most of the initial capital expenditures have already been made.

In addition, the university is a source of students who contribute substantially to achieving the RES's objectives. To quote from Frank Press, president of the National Academy of Sciences:

> Skilled and bright graduate students are one of the last remaining pools of high-quality labor in the world. Very few companies can match that talent, even at a much higher price.

Ongoing experiments at the Southwest RES include: evaluation of nine full-scale residential photovoltaic prototypes; testing thermal behavior of roof-mounted photovoltaic arrays; evaluating performance characteristics of a passive solar tracker; determining performance and maintenance sensitivity to inter-module wiring; and several others. We are also monitoring lived-in homes in Yuma, AZ, Albuquerque, NM, and Santa Fe, NM.

The visitor center is open to the public during working hours. Southwest RES personnel also give two tours per day, explaining experimental photovoltaic systems and other ongoing experiments. To date, 3,778 visitors from 40 of the 50 States and nine foreign countries have visited the Southwest RES.

The RES staff also give workshops throughout the Southwest. These introduce the concept of residential photovoltaic systems to a broad spectrum of the public, which includes homeowners, builders, financiers, code officials, architects, and businessmen.

Having presented the highlights of the photovoltaic system's test and evaluation program, I now come back to my recommendations. To repeat, I recommend that the photovoltaic program should continue a balanced program which includes systems research, research on distributed systems, small-scale systems experiments, and operation of the residential experiment stations.

I have talked about the benefits of my recommendations. Now I would like to dwell briefly on the consequences of not continuing these programs.

First of all, will the private sector pick up the costs? In my opinion, they will not. Quoting again from Frank Press:

> Industry's fraction of the total academic research budget in constant dollars has stayed between 3 and 4 percent the past 20 years. Of the leading 200 research universities, only 25 got more than 10 percent of their R&D expenditures from industry.

This indicates very clearly to me that: Research on utility interactive distributed systems will cease; systems experiments will be phased out; and the RES's will wither away.

Research on distributed systems is being pursued only under the Federal program. Utilities' interest lies primarily with central station applications. The photovoltaic industry also has an interest in domestic central station applications because of commercial energy tax credits which, under favorable conditions, make such applications profitable.

The net result of this is that no one would be looking after the interests of the individual homeowners. Without these systems experiments, there will be no development of complete residential-scale photovoltaic systems. As I have tried to indicate, reliably operating systems do not magically appear just because all the pieces have been developed. There is a risk that systems will be put on the market before they are safe and reliable.

This certainly was the case with solar heating systems, where well-publicized failures caused considerable distress to the solar industry. Controlled, behind-the-fence experiments lessen the likelihood of like disasters.

The RES staffs collectively have more than 50 man-years of photovoltaic systems experience. This assembly of talented and highly trained scientists, engineers, technicians, and students cannot be developed in short order. One hundred people working for one-half year would not yield a comparable 50-man-yea team of dedicated, experienced photovoltaic personnel. Much time will be lost rebuilding the existing capability.

In addition to loss of staff, there most assuredly would be a loss or scattering of valuable equipment. Data acquisition centers are more than a collection of hundreds of components and computers. Thousands of man-hours are hidden in the maze of wiring, printed circuit boards, and computer programs.

Experimental prototype structures and special test structures would also be dismantled and dedicated acreage used for other purposes. In short, physical aspects of the facilities would be lost.

The RES's are regional sources of reliable, unbiased information. Universities are respected by the public, in large measure, because of their professional and disinterested staff. Designers, architects, builders, bankers and potential photovoltaic systems users are receptive to what the RES's publish or present at meetings, workshops, and seminars. They value the opportunity to explore firsthand the reality of working photovoltaic systems at the RES's. These regional facilities form a unique framework for carrying out technology transfer.

In conclusion, I maintain that continued funding for photovoltaic systems research at the RES's is in the national interest. Furthermore, the research that I have discussed is highly cost effective because the equipment and trained staff are in place.

Madam Chairwoman, members of the subcommittee, I thank you again for the opportunity to testify.

[The prepared statement of Dr. Zwibel follows:]

# PROPER FEDERAL ROLE IN CONDUCTING RESEARCH AND DEVELOPMENT RELATED TO SOLAR ENERGY

Testimony by
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Given to
U.S. House of Representatives
Energy Development and Applications Subcommittee
of the
Committee on Science and Technology

February 29, 1984
Washington, D.C.

Chairman Fuqua, members of the subcommittee, I thank you for an opportunity to give my views on the proper Federal role in conducting research and development related to solar energy. I will focus my presentation on the Department of Energy's photovoltaic systems engineering and standards and test and evaluation program. In particular, I will address the three residential experiment stations (RES's) which are located in Concord, Massachusetts, Cape Canaveral, Florida, and Las Cruces, New Mexico.

The RES's form an integrated, nationwide network with major experimental responsibilities. They have an established record of achievements in distributed, grid-connected photovoltaic systems. As such, they are the main thrust for development of home-sized photovoltaic systems.

If I may leap ahead to the conclusion, my recommendation is that the Department of Energy maintain a balanced program that includes

- systems research,
- research on distributed systems,
- experimentation on small-scale systems, and
- operation of the residential experiment stations.

Before starting my technical presentation I would like to give you a brief overview of my background. I am director of the New Mexico Solar Energy Institute (NMSEI). NMSEI is a research institute at New Mexico State University which was established by the New Mexico State Legislature in July 1977. NMSEI is funded by the New Mexico State Legislature through the New Mexico Energy Research and Development Institute.

NMSEI's legislative mandate is

- to test and evaluate solar equipment and systems,
- to inform and educate the public, and
- to assist in the coordination of solar activities within the state.

The NMSEI staff of 37, with the support of 50 students, carry out projects in solar thermal, solar electric, wind, hydro, geothermal, and bioenergy. These activities range from component development to design, construction, and test and evaluation of full-scale systems. The information and education activities include workshops, publications, operation of the state's energy hotline, and curriculum development.

Prior to becoming NMSEI's director three years ago, I was head of the institute's photovoltaic division. I was project director of the Southwest Residential Experiment Station, about which I will say more later. I was also project manager of the El Paso 20-kilowatt photovoltaic experiment. This project was one of five to be funded in 1979 under Program Research and Development Announcement 38 (PRDA 38). This experience with photovoltaic system experiments over the last five and one-half years forms the basis for my testimony which follows.

In general, I believe that the Federal Government should carry out those activities that are necessary for the Nation's well-being and which can not be carried out in a timely fashion by the private sector. Solar energy research falls in this category because

- Congress has determined that a strong federal solar energy research development and demonstration program is in the national interest (1),
- most research can only be supported by established profitable businesses (2), and
- the photovoltaic industry is still in its infancy. For example, last year, only three U.S. companies sold more than 1 megawatt of photovoltaic modules. ARCO Solar, the largest, sold 6 megawatts out of the U.S. total of 13.1 megawatts of photovoltaic modules (3). It is not likely that enough capital is generated by the photovoltaic industry to carry out the research, development, and demonstration effort required.

In the following, I will discuss the need for systems research and development, which includes

- small-scale systems experiments,
- the residential experiment stations in general, and
- the Southwest Residential Experiment Station in particular.

By systems research and development I mean all the steps involved in advancing the state-of-the-art in complete, full-scale photovoltaic systems. It involves systems analysis, system design, system assembly, system test, and system evaluation. When we work with prototype system hardware, we do so at the smallest, most inexpensive scale possible, taking advantage of the modularity of photovoltaic systems.

In the systems R&D process, complex systems do not go directly from the laboratory to the field. Even though individual components have been tested and debugged, the interplay between these components in the real world invariably uncovers problems. Photovoltaic systems are sufficiently complex that there will be failures, which, let me stress, is natural and to be expected in the development process. For this reason, prototypes of complex systems must first be tested and evaluated in an experimental setting. And as I have already stated, the photovoltaic industry does not have the financial resources -- except under very unique circumstances -- to carry out these experiments to the extent necessary.

Small-scale systems experiments are designed to test and evaluate complete systems on the smallest possible scale that is large enough to operate realistically in the real world. Systems experiments play a vital role in the development of a multi-billion dollar photovoltaic industry. Systems experiments accomplish a variety of functions. They

- reveal catastrophic failures,
- evaluate components,
- provide quality performance data,
- identify interface problems,
- establish maintenance requirements,
- determine system reliability, and
- provide a technology data base.

I will amplify these points briefly.

Through careful monitoring of photovoltaic systems, the components are evaluated in the working environment. This often leads to design changes which improve component reliability and performance. One example that comes to mind has to do with the automatic shutdown of inverters should the photovoltaic system experience a loss of utility power. If the photovoltaic system does not shutdown in such cases, utility line workers would be exposed to dangerous voltages. It was found that both voltage and frequency deviations were necessary to insure shutdown.

Operating data from complete systems is needed in order to develop verified analysis tools. For example, work is currently underway using data from the Northeast and Southeast Residential Experiment Stations to determine the accuracy of PV/F-CHART (4). This photovoltaic analysis program is one of several that will be evaluated. Reliable analytical methods are needed in order to assess potential system modifications and to predict performance in different locations.

Only through operation in the real world can potentially difficult interface problems and issues be resolved. Utility interactive photovoltaic systems must operate in a safe and benign manner with the utility grid. Some of the problems to be resolved are the effects due to ac wave form quality, fail safe shutdown in order to protect utility personnel, and protection of the photovoltaic system from the utility system.

The true cost of photovoltaic energy depends not only on the system first cost, but also on maintenance costs. Operation and maintenance costs can mean the difference between profit or loss for a commercial photovoltaic system installation. This is shown quite clearly in a paper that is included with my written testimony (5). Inexpensive methods must be developed for the maintenance of photovoltaic systems. This would include "failure" detectors and effective repair/replacement procedures. A better understanding of these maintenance costs will help to quantify the value of rugged, reliable components.

Potential users need assurance that complete systems will perform as predicted. They need to know how reliable the systems are in order to establish potential savings and/or profit. Utilities and insurers must understand that photovoltaic systems will operate safely and reliably. Otherwise, exorbitant amounts of insurance will be required at high cost to the user.

One aspect of systems experiments that is very important is the information exchange that occurs between the researchers and the potential users. This transfer of systems research results must take place if photovoltaic technology is to find widespread acceptance by designers, planners, builders, and potential users. To quote from William Patrick Collins, Undersecretary of Energy, "Technology transfer is a vital key in the research and development process" (6). I could not agree more strongly.

I would now like to discuss the residential experiment stations. The three residential experiment stations are

- the Northeast Residential Experiment Station located in Concord, Massachussetts, and operated by the Massachusetts Institute of Technology,
- the Southeast Residential Experiment Station located in Cape Canaveral, Florida, and operated by the Florida Solar Energy Center for the University of Central Florida, and
- the Southwest Residential Experiment Station (SWRES) located in Las Cruces, New Mexico, and operated by the New Mexico Solar Energy Institute, for the New Mexico State University.

The RES's were established for the residential photovoltaic program and currently have a major role in that program. In addition, their responsibilities have been broadened to include non-residential photovoltaic experiments. Because of the broadened scope of their work, and because each RES serves a distinct geographical and climatic region, they might more appropriately be called regional experiment stations.

Key features of the RES's follow.

- Each RES covers an extreme climatic region of the country.
- Each is located in a state that strongly supports solar energy research.
- Each is affiliated with a major university.
- Each is fully established with state-of-the-art data acquisition equipment, support facilities, full-scale residential prototypes (there are a total of 17 prototypes), and specialized test structures.
- Each is staffed with experienced, qualified, and enthusiastic staff.
- The RES's are extremely cost-effective to operate.
- And finally, the RES's are a unique source of knowledge on the operation of utility interactive photovoltaic systems.

Picking up on the last point, data has been gathered at the RES's for over three years on a variety of residential prototypes. These unoccupied structures mechanically, thermally, and electrically produce an environment for roof-top mounted photovoltaic systems that is identical to that of actual lived-in residences. This detailed and comprehensive data base is being used to determine system performance, reliability and degradation, and to verify analysis methods.

The RES staffs also conduct specific experiments, including

- photovoltaic system/utility interface experiments,
- photovoltaic array thermal tests,
- evaluation of photovoltaic array mounting methods,
- irradiance tests to assess solar tracking, and
- tests on the effect on performance of different inter-module wiring schemes.

As the economics of photovoltaic systems improve, home owners, homebuyers, builders, and businessmen may create a significant demand for photovoltaic systems. The residential experiment stations now play a vital role in preparing for this likely demand by developing a comprehensive data and information base. The following issues are of particular importance:

- system installation for both new and retrofit construction,
- system safety and reliability,
- design guides and methods, and
- utility interface concerns.

System installation, both for new and retrofit construction, must be thoroughly researched and analyzed. Efficient and economical methods for integration and installation of photovoltaic arrays must be developed. Roof-top photovoltaic systems installation will involve a variety of trade jurisdictions, including workers in the current solar industry, electricians, roofers, and carpenters. Finding an acceptable division of labor will require a cooperative effort among the concerned groups. The RES's are capable of performing construction/installation task analyses that will contribute to resolving this process. In addition, the RES's are ideally suited for the hands-on education that would be required.

Because of the large investments required for residential photovoltaic systems, buyers need to be assured that the system will operate safely and reliably. The RES's are providing an unbiased data base for both component level and system level performance, reliability and durability. Manuals on the design, installation, and construction techniques for both photovoltaic systems and buildings that will use photovoltaic systems are being prepared for the housing industry. Input to this growing data base comes from all three RES's in order to include the effects of different climates and to respond to regional construction practices.

Photovoltaic system designers need simplified design and sizing guidelines, handbooks, and catalogs for both utility interactive and stand-alone applications. Builders, developers and contractors need information on labor and equipment requirements, and on the costs and availability of photovoltaic equipment. The RES's can also provide needed hands-on work experience with photovoltaic systems.

Problems and concerns of utilities must be identified and addressed if interconnection is not to be a major barrier to market penetration of residential photovoltaic systems. The RES work will prove useful in assisting utilities and public utility commissions in developing "reasonable" interconnection requirements and "avoided-cost" rates for grid-interactive systems. The experimental and analytical work in this area is, and will continue to be, closely coordinated with the regional utilities.

I would now like to discuss the SWRES. Please bear in mind that the other two RES's could give similar accounts of their experiences; I have chosen the SWRES for convenience, since I am most familiar with it. The SWRES employs a professional on-site staff of four, a highly experienced electronics technician, and fourteen New Mexico State University engineering students. They form a team that collectively has more than 18 man-years of photovoltaic systems experience. In addition to the SWRES-supported staff, NMSEI graphic, secretarial, editorial, and management assistance is available as required at no charge to the project.

The experiment station itself is situated on three acres of university land that is given without charge to the SWRES. It is choice land, only 50 yards from the highly traveled Interstate 10 highway. The photovoltaic center is a 3,000 square foot building that houses the offices, workshop, data acquisition and computer room, and visitor center. Funding for this building was provided by the state of New Mexico under the Energy Research and Development Program. I would like to emphasize that the capital equipment, such as computers, data sensors, shop equipment, and nine full-scale experimental photovoltaic systems, is all paid for and in use. Continued operation of the SWRES (in fact of all the RES's) is cost effective because most of the initial capital expenditures have already been made. In addition, the university is a source of students who have sufficient training to contribute substantially to achieving the RES's objectives. To quote from Frank Press, President of the National Academy of Sciences, "...skilled and bright graduate students are one of the last remaining pools of high-quality labor in the world. Very few companies can match that talent, even at a much higher price" (7).

Ongoing experiments at the SWRES include

- evaluation of seven full-scale residential photovoltaic prototypes,
- testing thermal behavior of roof-mounted photovoltaic arrays,
- evaluating performance characteristics of a passive solar tracker,
- designing, testing, and evaluating a low-cost dc to dc converter,
- determining performance and maintenance sensitivity to inter-module wiring,
- assessing photovoltaic system/utility interface issues,
- devising maintenance strategies, and
- monitoring lived-in homes in Yuma, Arizona, Albuquerque, New Mexico, and Santa Fe, New Mexico.

Technology transfer at the SWRES occurs at all levels. The visitor center is open to the public during working hours. A programed slide show introduces the visitor to the RES and to photovoltaics. Displays contain examples of all the modules in use on the prototypes at the SWRES. Brochures which describe each experimental photovoltaic system are available without charge. The visitor center presents a simple, concise introduction to residential photovoltaics and to the national program that is working to bring it to reality. To date, 3,778 visitors have visited the SWRES. They have come from 40 of the 50 states and 9 foreign countries.

SWRES personnel give two tours per day explaining the experimental photovoltaic systems and other ongoing experiments. In addition, special tours are arranged for groups such as civic organizations, school classes, state legislators, and visiting dignitaries.

SWRES staff, with the support of nationally recognized photovoltaic experts, give workshops for the public throughout the Southwest. These introduce the concept of residential photovoltaic systems to a broad spectrum of the public, which includes homeowners, builders, financiers, code officials, architects, and businessmen. These workshops are an effective method for transferring the "photovoltaic experience" to the public. Nothing beats face-to-face sessions with articulate experts for disseminating technical information. As an aside, NMSEI gives about 50 solar energy workshops a year throughout New Mexico.

Having presented the highlights of the photovoltaic systems tests and evaluation program, I would now like to come back to my recommendations. To repeat, I recommend that the photovoltaic program should continue a balanced program which includes

- systems research,
- research on distributed systems,
- small-scale systems experiments, and
- operation of the residential experiment stations.

I have talked about the benefits of each of my recommendations. Now I would like to dwell briefly on the consequences of not continuing these programs.

First of all, will the private sector pick up the costs? In my opinion, they will not. Quoting again from Frank Press, "...industry's fraction of the total academic research budget in constant dollars has stayed between three and four percent the past 20 years...of the leading 200 research universities, only 25...got more than 10 percent of their R&D expenditures from industry" (7). This indicates very clearly to me that

- research on distributed systems will cease,
- systems experiments will be phased out, and
- the RES's will wither away.

The consequences of these actions would be far reaching.

Research on distributed systems is being pursued only under the federal program. Utilities' interest, when there is an interest, lies primarily with central station applications. The photovoltaic industry also has an interest in domestic, central station applications, primarily because of commercial solar energy tax credits -- reference (5) shows quite clearly that under favorable conditions, and sufficient tax credits, such commercial applications could be profitable. The net result of this is that no one would be looking after the interests of individual home owners.

Without systems experiments there will be no development of complete photovoltaic systems. As I have tried to indicate, reliably operating systems do not magically appear just because all the "pieces" have been developed. There is a risk that systems will be put on the market before they are safe and reliable. This certainly was the case with solar heating systems where well-publicized failures caused considerable distress to the solar industry. Unfortunately, human nature being what it is, people place much more emphasis on failures than on successes. Controlled, behind-the-fence systems experiments lessen the likelihood that such disasters will befall the photovoltaic industry.

The RES's staffs collectively have more than 50 man-years of photovoltaic systems experience. This assembly of talented and highly trained scientists, engineers, technicians, and students can not be developed in short order. One-hundred people working for one-half year would not yield a comparable 50 man-year team of dedicated, experienced photovoltaic personnel. Much time will be lost rebuilding the existing capability.

In addition to loss of staff, there most assuredly would be a loss or scattering of valuable equipment. Data acquisition centers are more than a collection of hundreds of components and computers. Thousands of manhours are hidden in the maze of wiring, printed circuit boards and computer programs. Experimental prototype structures, and special test structures would also be dismantled and dedicated acreage used for other purposes. In short, physical aspects of the facilities would be lost.

The RES's are regional sources of reliable, unbiased information. Universities are respected by the public, in large measure, because of their professional and disinterested staff. Designers, architects, builders, bankers, and potential photovoltaic system users are receptive to what the RES's publish or present at meetings, workshops, and seminars. They value the opportunity to explore first hand the reality of working photovoltaic systems at the RES's, knowing that no one is pressuring them to "buy now." These regional facilities form a unique framework for carrying out technology transfer at the most basic, one-on-one level.

In conclusion, I maintain that continued funding for photovoltaic systems research, especially for systems interfacing with the electric power grid, is in the national interest. Furthermore, the research that I have discussed is highly cost-effective because

- most of the needed funding has already been spent for equipment in place,
- the testing needs to be done at universities, not only because industry can't afford it, but also for credibility, and
- the payoff for the U.S. in the world competition for the anticipated multi-billion dollar photovoltaic market could be enormous.

Chairman Fuqua, members of the subcommittee, I thank you again for the opportunity to testify.

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# ECONOMICS OF BUSINESS INVESTMENTS IN RENEWABLE ENERGY SYSTEMS

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## ABSTRACT

The costs of renewable energy systems are sensitive, economically, to both operational and financial parameters. The objectives of this paper are (1) to identify the ranges of the parameters which yield achievable break-even costs for renewable energy systems and (2) to determine the sensitivity of the break-even cost to parameter variations. The break-even price is a function of system characteristics, tax credits, market conditions, financing details, and electric energy rates.

The analysis defines each system in terms of rated capacity, capacity factor, expected life, and operation and maintenance costs. The financial input includes loan fraction, loan duration, interest rate, marginal tax rate, required rate of return, tax credits, depreciation schedule, property taxes, and insurance. The time variation of the electric cost is given in terms of escalation rates which can be changed annually. Market conditions are given in terms of an inflation factor. Three electrical generating systems, photovoltaic arrays, wind turbine generators, and small-scale hydroelectric generators, are used to evaluate the effects of varying the parameters.

Results from the analysis show that both wind generators and PV systems (1) require incentives or subsidies in addition to the combined 25 percent federal investment tax credits, (2) are cost effective only if long-term financing at favorable interest rates can be secured from lending institutions, and (3) must achieve long system lifetimes to be economically feasible. In addition, operation and maintenance costs have a strong impact on system economics. It is, therefore, important to determine and document performance and operation and maintenance requirements of field-installed systems in future research activities.

## INTRODUCTION

This paper investigates the economic conditions under which renewable energy systems become cost effective for a business. Three renewable energy technologies are discussed: photovoltaic systems, wind generatorr, and small-scale hydroelectric plants. The emphasis of the study is on determining the impact that renewable energy system investment tax credits, operation and maintenance, and system lifetime have on the economics of a renewable energy system. The study is limited to commercial sized systems (about 100 kilowatts) which are treated as a business investment. The economics of smaller residential type systems are not discussed.

Because most state tax incentives are relatively small as a percentage of the cost of commercial sized systems and because only the federal tax credits for renewable energy systems are available in all states, individual state tax incentives are not discussed. However, the impact of one strong incentive supplementing the federal tax credit is investigated. Results from the study are presented as a break-even cost versus a variety of economic conditions.

## TECHNOLOGIES AND THEIR COST

Three types of electric generating systems using renewable energy technologies, photovoltaic arrays, wind turbine generators, and small-scale hydroelectric generators are examined. Table 1 summarizes the costs and capacities for each technology. The efficiency and cost of each type of system are outlined below and form the basis for subsequent calculations and discussions.

TABLE 1.
Cost of Three Renewable Energy Systems

| System | Cost Range $1,000/kw | Capacity Factor | Cost/Average Output $1,000/kw |
|---|---|---|---|
| PV | 8 - 12.0 | 0.25 | 32.0 - 48.0 |
| Wind | 1 - 2.5 | 0.20 | 5.0 - 12.5 |
| Hydro | 1 - 3.0 | 0.60 | 1.6 - 5.0 |

### PHOTOVOLTAIC ARRAYS

In the photovoltaic (PV) process, incident radiant energy is converted directly into direct current (dc) electrical power by means of a semiconductor photovoltaic cell. Typical conversion efficiencies of commercially available PV cells are around 10 percent. The dc power produced from the PV array may be stored in batteries or converted to utility compatible alternating current (ac) power by use of a synchronous inverter. For this paper, only utility interconnected systems will be considered. From our work and experience at the Solar Energy Institute, we estimate the current (1983) cost range of flat-plate photovoltaic arrays to be from $8,000 to $12,000 per installed kilowatt peak power. This cost includes the required synchronous inverter and utility interconnection. For the remainder of the paper, we assume a PV capacity factor of 0.25, which is typical for a flat-plate photovoltaic array operating in the southwestern United States (1). We can now estimate the cost of PV systems per average system output by dividing the installed cost per peak kilowatt by the capacity factor. By calculating and using the cost per average power output, a comparison of the cost of different technologies is straightforward. For photovoltaic systems, the cost range becomes $32,000 to $48,000 per average kilowatt output produced.

### WIND TURBINE

Wind turbine generators extract mechanical power from the wind with an aerodynamically designed rotor. The rotor drives an electrical generator to produce either ac or dc power. DC wind generators require a synchronous inverter for utility interconnection. Based on our personal communications with manufacturers and out field experience, we estimate that the cost range of commercially available wind generators is between $1,000 to $2,500 per installed rated kilowatt (see, also, reference 2). If installed in a moderate wind regime (e.g., wind speed class 4 as defined by Battelle Pacific Northwest Laboratory (3)), a wind generator will typically operate at a capacity factor of 0.2. The cost range per average power produced from a wind generator then is $5,000 to $12,500 per kilowatt.

### HYDROELECTRIC POWER PLANTS

Small-scale hydroelectric power plants extract power from the flow of water falling through a head of a few feet to several hundreds of feet. Often, small-scale hydroelectric plants are installed or planned at existing dams which were originally built for other purposes, such as for flood control or for water supply reservoirs. In these cases a major cost item for small hydroelectric installations is already in place and does not need to be financed. The installed cost of small hydroelectric systems falls in the range of $1,000 to $3,000 per kilowatt (4). Run-of-the-river hydroelectric plants are designed for and typically operate at a 0.6 capacity factor. This results in a cost range from about $1,600 to $5,000 per average kilowatt output.

## CALCULATIONS

The calculations of the economics of renewable energy systems presented in this paper are based on a model developed for the Electric Power Research Institute (1). The model calculates a break-even cost ($/kw) of a renewable energy system. This break-even cost is the maximum allowable system price the user can afford to pay and realize the returns specified. Mathematically, the break-even cost is that cost per kilowatt which causes the net present value of all cash flows to be zero. Table 2 is a list of program inputs and the values or ranges used in the following calculations.

TABLE 2.
Model Input Parameters

| | |
|---|---|
| Analysis Period | 20 years |
| Debt Fraction | 75% |
| Cost of Debt | 14%, 18% per year |
| Loan Period | 5, 15 years |
| Required Rate of Return | 21% |
| General Inflation | 5.5% per year |
| Tax Credit | 10%, 25%, 55% |
| Marginal Tax Rate | 50% |
| O&M Cost | 3% of system cost |
| Capacity Factor | 1 |
| Depreciation | 5 years |
| Displaced Electric Value | 3, 6 cent/kwh |
| Escalation of Electricity | 8% per year |

Two loan scenarios for financing the system are presented: (1) a short-term loan (5 years) with an annual interest rate of 18 percent, and (2) a long-term loan (15 years) with an annual interest rate of 14 percent. Both loans assume a debt fraction of 75 percent of the system cost. All calculations set the required rate of return to 21 percent. General inflation is fixed at 5.5 percent per year, thus escalating the operation and maintenance costs at that rate. The value of the displaced electricity is escalated at 8 percent per year. The systems are depreciated over 5 years using the 200 percent declining balance method.

It is interesting to note that the break-even cost is directly proportional to both the capacity factor and the first year displaced electricity value. We have, therefore, set the capacity factor to one in all calculations and the electricity value to three cents or six cents per kilowatt-hour. For different capacity factors or electricity values, the presented curves can be adjusted easily. For example, for capacity factors other than one, simply multiply the curve shown by the new capacity factor.

It is further worth noting that the physical differences of the different technologies enter only in the capacity factor.

The expressions of the economic model were entered into a spread sheet program on the IBM personal computer. To accomplish this, several summations were reduced to their closed form solutions and programmed into the spread sheet. Quick and efficient evaluation of numerous economic conditions was thus possible.

## RESULTS

The calculations were aimed at studying the effects on the system economics from varying tax credits, the influence of operation and maintenance costs, and the dependence on system life. A summery of the parameters used in calculating the curves for tax credit effect at varying levels of cost per kilowatt- hour, costs of operation and maintenance, and effect of system life are provided in table 3. The figures are discussed in detail below.

TABLE 3.
Summary of Parameters for Figures 1 to 7
v = variable

| Parameter | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Analysis Period (y) | 20 | 20 | 20 | 20 | 20 | 20 | v |
| Debt Fraction (%) | v | v | v | v | 75 | 75 | 75 |
| Cost of Debt (%) | 18 | 18 | 14 | 14 | 18 | 14 | 18 |
| Loan Period (y) | 5 | 5 | 15 | 15 | 5 | 15 | 5 |
| Rate of Return (%) | 21 | | | | | | |
| Inflation (%) | 5.5 | | | | | | |
| Tax Credit (%) | v | v | v | v | 25 | 25 | 25 |
| Tax Rate (%) | 50 | | | | | | |
| O&M Cost (%) | 3 | 3 | 3 | 3 | v | v | 3 |
| Capacity Factor | 1 | | | | | | |
| Depreciation (y) | 5 | | | | | | |
| Electrical (c/kwh) | 3 | 6 | 3 | 6 | v | v | 6 |
| Escalation (y) | 8 | | | | | | |

### EFFECT OF TAX CREDIT

Figure 1 depicts a plot of the break-even cost of renewable energy systems versus the loan fraction for the short-term loan (5 years at 18 percent annual interest rate). The calculations assume a three cents per kilowatt-hour first year displaced electric value. The three different curves represent the standard 10 percent business investment credit, a 25 percent investment tax credit (10 percent business investment credit and 15 percent renewable energy investment credit), and a 55 percent tax credit, as might be realized in some states.

Also shown in this and the following diagrams are the cost ranges of the three technologies. Since the break-even cost is the maximum allowable cost the user can pay, only those parts of the curves that exceed the individual cost ranges represent economically viable options.

As can be seen, the break-even cost rises steeply above a 50 percent loan fraction for the 55 percent tax credit (TC) incentive, whereas it is nearly independent of the loan fraction for the lower tax credits. The dramatic favorable impact of a strong tax incentive is obvious. Figure 2 shows the break-even cost assuming the short-term loan and a six cents per kilowatt-hour displaced electric value. In this analysis, for the

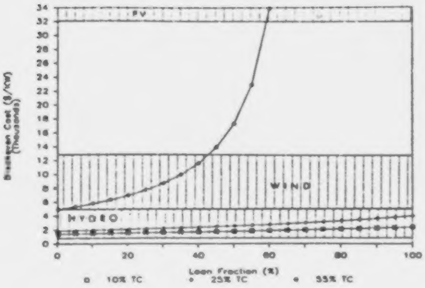

Figure 1. Tax credit effect ($0.03/kwh).

displaced electric value of six cents per kilowatt-hour and a 55 percent tax incentive, most wind turbine generators become an attractive investment if at least 20 percent of the installed cost can be financed by a short-term loan. This is not the case when the tax credit is only 25 percent. Here, only the lower priced wind systems become cost effective when heavily financed.

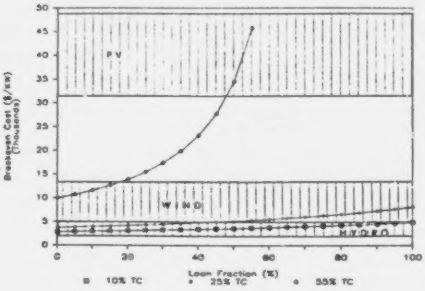

Figure 2. Tax credit effect ($.06/kwh).

The impact of a strong tax incentive is even more pronounced for the longer term loan (15 years at 14 percent annual interest rate), figures 3 and 4. In figure 3, the break-even cost rises sharply above a debt fraction of 25 percent for the 55 percent tax credit, and above 80 percent debt fraction for the standard federal 25 percent tax credit.

If more favorable long-term financing can be secured, the outlook for wind and PV systems is improved. Figures 3 and 4 depict the results for initial displaced electricity values of three cents per kilowatt-hour and six cents per kilowatt-hour respectively. Particularly in the latter case, figure 4, even the relatively expensive PV energy systems become an attractive investment at a 55 percent tax credit, if financing for at least 25 percent of the system cost can be arranged. Similarly, for the lower federal tax credit of 25 percent, a PV system remains cost effective if more than 80 percent of the system cost can be financed by a long-term loan.

Most wind systems are economically attractive at any debt fraction if a 55 percent tax credit is available.

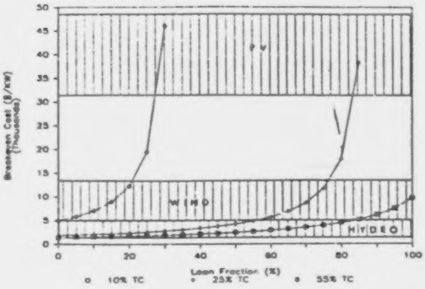

Figure 3. Tax credit effect ($0.03/kwh).

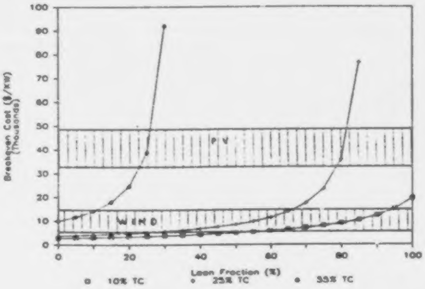

Figure 4. Tax credit effect ($.06/kwh).

However, at least 65 percent project cost financing is required to make a wind generator cost effective if only the 25 percent federal tax credit is available. Hydroelectric installations are extremely favorable under the conditions described in figure 4 and do not necessarily require specific tax incentives.

## IMPORTANCE OF OPERATION AND MAINTENANCE COSTS

Figures 5 and 6 show the dependence of the break-even cost on the operation and maintenance costs. The operation and maintenance costs include the cost of operating and maintaining the system as well as the annual insurance cost and property taxes. In figures 5 and 6, 75 percent of the system is financed with a short-term loan and a long-term loan, respectively. The cost ranges of the three technologies are also indicated on the figures. Only the 25 percent federal tax credit is presented.

As one might expect, the break-even cost decreases with increasing operation and maintenance costs. This effect is quite strongly pronounced in figure 6, which represents the long-term loan. Under these conditions, PV systems that require more than 1.5 percent to 2.5 percent operation and maintenance costs are no longer effective. The economics of wind systems becomes marginal if the required operation and maintenance costs exceed 3.5 percent for a three cents per kilowatt-hour electric rate, or 5 percent for a six cents per kilowatt-hour electric rate. This raises an important point. Since both wind and PV technology are relatively new, real-life operation and maintenance costs have not been

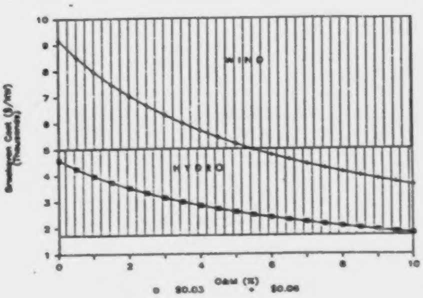

Figure 5. Importance of operation and maintenance costs (short-term loan).

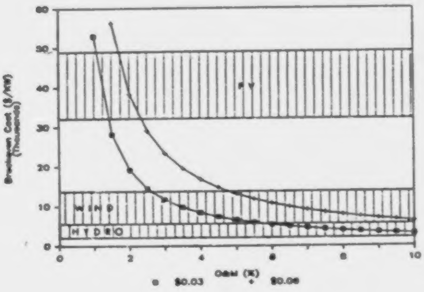

Figure 6. Importance of operation and maintenance costs (long-term loan).

well established. Little operational data are available on field installations of these systems; yet the operation and maintenance costs strongly influence the economic attractiveness of these systems. To establish the confidence of users and financial markets in these systems, it is, therefore, important to continue efforts to monitor and document the performance of wind and PV systems under real world conditions.

## EFFECT OF SYSTEM LIFE

The effect that the system life has on the break-even cost is depicted in figure 7 for the short-term loan. System life for PV and wind generators is generally assumed to be 20 years or more; yet virtually no field data confirming this lifetime are available. Catastrophic failures can and have occurred, rendering the system useless after a few years of operation. Under the conditions of figure 7 (see table 3 for the parameters used) the lowest priced wind system ($5,000 per average kilowatt produced) has to perform at least for 10 years to achieve the 21 percent required rate of return. A shorter lifetime will cause a loss, whereas a longer lifetime will increase the rate of return. Although figure 7 does not explicitly show PV, our calculations show the same influence of system life on the break-even cost for PV installations as for wind generators. Hydroelectric generators, because of their lower cost per power produced, outperform wind generators and PV systems and achieve cost effectiveness in much shorter lifetimes of 2 to 10 years.

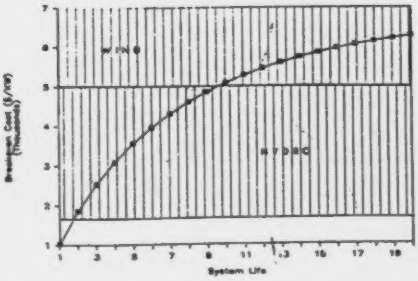

Figure 7. Effect of system life.

## CONCLUSIONS

We can draw the following conclusions from the calculations presented in this study.

1. At the current cost, tax incentives in excess of the combined 25 percent federal business investment credit and renewable energy investment credit are necessary to stimulate widespread implementation of wind turbine generators and PV systems. We, therefore, advocate not only an extension of the federal renewable energy investment tax credit past its current expiration date of December 31, 1983, but also increase in the current 15 percent rate to make the investment incentive more attractive.

2. Most small-scale hydroelectric generators may not require these additional incentives.

3. Wind and PV systems are generally cost effective only if favorable long-term financing can be obtained for a major fraction of the system cost. Continued efforts by the renewable energy industry to increase the willingness of financial institutions to grant long-term loans for wind, PV, and small hydroelectric systems are highly recommended.

4. Operation and maintenance costs are critically influencing the system break-even cost. Future research to determine the real world performance and operation and maintenance requirements of field-installed systems is important to establish the confidence of the user and the financial market.

5. Wind and PV systems must accomplish long system lives to become attractive investments.

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Mrs. **Schneider.** Thank you very much.

Am I pronouncing your name correctly? Is it Dr. Feucht?

Dr. **Feucht.** That is right.

Mrs. **Schneider.** All right. Would you please enlighten us with your testimony? I would appreciate it if you could please summarize your remarks, because that was quite a "bible" that you presented us with, and your entire statement will be incorporated into the record, but if you could summarize, it would be greatly appreciated.

Thank you.

Dr. **Feucht.** Thank you, Madam Chairman.

## STATEMENT OF DR. DONALD L. FEUCHT, DEPUTY DIRECTOR, SOLAR ENERGY RESEARCH INSTITUTE

Dr. **Feucht.** Thank you for the opportunity to describe the advanced research component of the photovoltaic research and development program which the Solar Energy Research Institute manages for the U.S. Department of Energy's Photovoltaic Energy Technology Division.

Today I will report on the strength of the U.S. technology, the progress being made toward meeting or exceeding the goals of the National Photovoltaics Program's Five Year Research Plan, and the exciting prospects for future advancements in this important renewable energy program.

The high-quality research teams assembled at program field centers and in industry and university organizations already have addressed many difficult scientific and technical problems in the photovoltaics field. Their progress has been the result of continued Government support of the program.

During the past 5 years, the program has become more focused, and as we have built on past progress and new knowledge, we have reduced the number of options and parallel paths being pursued. The program continues to be strong, as you will be able to conclude from this testimony.

Field management and implementation of the photovoltaics program objectives are carried out by three major DOE-funded research centers: the Jet Propulsion Laboratory, Sandia National Laboratories, and the Solar Energy Research Institute. Each center is responsible for day-to-day management of specific research activities, including the performance of in-house research and guidance of work subcontracted to industry and universities.

Numerous technical achievements have resulted from this combination of resources. For example, the conversion efficiency of laboratory-produced photovoltaic cells made of silicon has increased from 11 to 18 percent and from 2 to nearly 11 percent using advanced thin-film cells.

In addition, module life expectancy, once estimated to be 1 to 5 years, has been increased to more than 10 years.

Techniques have been developed to increase the efficiency of cell and module production. Industry has applied these techniques effectively, reducing module production costs approximately five-fold since 1975.

The U.S. photovoltaic industry has established itself as the world leader, accounting for 58 percent of the market share in 1982 despite significant advances made by foreign competitors in Japan and Western Europe.

This briefly summarizes some of the major accomplishments of the photovoltaic program as a whole. I would now like to focus, as requested by the subcommittee, on the advanced photovoltaic research managed by SERI. There have been significant accomplishments in advanced solar cells in the last 5 years.

These include: the achievement of the intermediate goal of 10 percent conversion efficiency in several different types of thin-film material cells, including amorphous silicon, copper indium diselenide, cadmium telluride, and polycrystalline silicon; the development of stacked multijunction cells with efficiencies approaching 22 percent; third, the demonstration of long-term stability for copper indium diselenide solar cells; fourth, the measurement of a large amorphous silicon submodule greater than 7 inches by 7 inches square with an efficiency of 4.4 percent; and the initiation of new amorphous silicon program thrusts intended to revitalize the Nation's effort in a field which the Japanese are now rapidly developing.

Even though the costs of flat-plate silicon modules have continued to decrease and efficiencies increase, it is this thin-film technology which I believe holds great promise for low-cost options. This effort is managed through SERI's Solar Electric Research Division and includes in-house research, device measurement and testing, and research management of numerous subcontracts with industries and universities.

The national photovoltaic 5-year research plan has focused the PV program on those research areas which hold the most promise as a base for technologies to be developed by industry.

In formulating these plans, the national program has worked to foster a strong Federal-industrial partnership and has integrated recent analyses done by the Electric Power Research Institute and DOE's Solar R&D panel of the Energy Research Advisory Board.

The three major areas selected for the advanced research component of the photovoltaics R&D program are: amorphous thin films, polycrystalline thin films, and advanced high efficiency concepts.

All hold high promise of meeting or exceeding the established research goals. A broad-based program was carried out between 1978 and 1983 for a wide range of candidates. The progress was quite good, as evidenced by the dramatic and continued improvements in device efficiency.

I would now like to briefly discuss each of these areas; first amorphous thin films. Although 10 percent efficient small area amorphous silicon cells have been reported in both the United States and Japan, we have yet to achieve long-term stability and high efficiency for large area cells. In 1983, a competitive research program involving cost sharing with industry was initiated to improve the cell efficiency and stability of single-junction amorphous silicon cells. This 3-year phased program is designed to develop stable submodules with efficiencies of 8 percent and small cells with efficiencies greater than 12 percent.

A closely related program on multijunction cells was also initiated in 1983 to identify and develop new amorphous silicon alloy materials and new multijunction cells, with a long-term objective of achieving greater than 20 percent cell efficiencies.

In the polycrystalline thin film area, the maximum efficiencies achieved for small, thin-film cells are 10 to 11 percent, and for larger cells, 7.5 percent. Although these efficiencies are lower than for crystalline silicon, selected materials offer a long-term potential to yield cell efficiencies as high as 18 percent.

Several polycrystalline compound semiconductors under investigation have already shown increases in efficiency and improved stability characteristics. For example, copper indium diselenide cells have achieved efficiencies approaching 11 percent with demonstrated stability under continuous illumination and elevated temperatures for more than 9,000 hours.

Areas for future investigation in polycrystalline thin films include the mechanisms limiting achievement of efficiencies approaching the theoretical maximum of 20 percent or greater for copper indium diselenide, cadmium telluride, and zinc phosphide.

In regard to advanced high efficiency concepts, this task supports research on solar cell designs and materials with the objective of achieving the maximum attainable photovoltaic conversion efficiencies. This research is directed toward achieving 35 percent or greater efficiency in solar cells under highly concentrated sunlight and thin-film solar cells with one-sun efficiencies of 17 to 20 percent for use in very high efficiency, multibandgap, thin-film solar cells.

The materials being studied are generally gallium arsenide-based or gallium arsenide-like materials. Although these materials are expected to be more expensive than some of the other thin-film materials, their costs may well be offset by higher efficiencies.

Crystalline silicon technology is well developed; thus, it is the subject of less extensive research. Expected results include an improved understanding of crystalline silicon solar cell physics and design; improved efficiency; improved understanding of the chemistry, physics, structure, and properties of electrically active defects and how these can be passivated by hydrogen.

In each of these areas, SERI conducts both in-house research tasks and subcontracted research. In-house, we are also continuing to develop, implement, and provide new and state-of-the-art measurement and device capabilities for the improvement of advanced R&D cells and materials, in cooperation with and in support of subcontracted and internal research activities.

In this regard, SERI supports the DOE decision to request photovoltaic capital equipment funds to maintain present state-of-the-art capabilities.

The continued exploration of new concepts and materials is vital to the long-term development of direct solar energy conversion, and the photovoltaic program continues to seek methods to solicit innovative ideas from industry and universities.

At the request of DOE, we are developing a new initiative for fiscal year 1985 for a multiyear, multiparticipant grants program to offer basic and applied research funds to qualified universities through a competitive procurement process.

The purpose of the program is to attract the most qualified university research teams to the national photovoltaics program. The initiative would provide continuity of funding over a minimum 3-year period. This should stimulate universities to build and support interdisciplinary teams with specialized expertise which can then be applied to further the photovoltaics technology base. Such a program would also support technology transfer to industry by training qualified graduates and by publication of research results in the technical literature.

Finally, I would like to comment on two technology cross-cutting areas which contribute not only to the strength of the photovoltaics research and development program but to SERI's solar research program as a whole. The insolation and renewable resource assessment project is one such effort.

Over the past several years, this project has focused on evaluating the effects of the solar spectrum on photovoltaic cell and system performance and their impact on advanced photovoltaic cell performance and system requirements. Similar information is also applicable to the development of other solar technology areas.

In photoconversion, which is a broader area also related to photovoltaics, many opportunities exist to develop the use of solar photons as the primary energy source for the production of electricity and certain fuels and toward improvements in photoelectrochemistry and dissociation of water to produce hydrogen. Basic research supported by the Basic Energy Sciences Program of DOE has demonstrated that this is a promising long-term research area.

The national photovoltaics program is strong and has achieved significant advancements over the past 5 to 7 years. Efforts during the next 5 years hold high prospects for equal progress.

Thank you for allowing me the opportunity to share my enthusiasm for the progress and potential of the photovoltaics research program and for that portion managed and conducted by SERI.

I will be happy to answer any questions from the subcommittee.

[The prepared statement of Dr. Feucht follows:]

**Statement of**

**Dr. Donald L. Feucht**
**Deputy Director**
**Solar Energy Research Institute**
**Golden, Colorado**

**Before the**
**Subcommittee on Energy Development**
**and Applications**

**Committee on Science and Technology**

**U.S. House of Representatives**

**February 29, 1984**

Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to describe the advanced research component of the Photovoltaic Research and Development Program which the Solar Energy Research Institute (SERI) manages for the U.S. Department of Energy's Photovoltaic Energy Technology Division. This program is funded by DOE through a contract with the Midwest Research Institute (MRI), Kansas City, Missouri, for the operation of SERI. It has been five years since I appeared before this Subcommittee and described our then newly developed program. Today I am pleased to report on the strength of the United States' technology, the progress being made toward meeting or exceeding the goals of the National Photovoltaics Program's Five Year Research Plan, and the exciting prospects for future advancements in this important renewable energy program. The high-quality research teams assembled at Program field centers and in subcontractor industry and university organizations have already addressed many difficult scientific and technical problems in the photovoltaics field. Their progress has been the result of continued Government support of the Program. During the past five years the Program has become more focused, and as we have built on past progress and new knowledge, we have reduced the number of options and parallel paths being pursued. The Program continues to be strong as you will be able to conclude from this testimony.

Field management and implementation of the Photovoltaics Program objectives are carried out by three major DOE-funded research centers: the Jet Propulsion Laboratory (JPL) in Pasadena, California; Sandia National Laboratories (Sandia) in Albuquerque, New Mexico; and the Solar Energy Research Institute (SERI) in Golden, Colorado. Each center is responsible for day-to-day management of specific research activities, including the performance of in-house research and guidance of work subcontracted to industry and universities. Numerous technical achievements have resulted from this combination of resources. For example, the conversion efficiency of laboratory-produced PV cells has increased from 11% to 18% using crystalline silicon and from 2% to nearly 11% using advanced thin-film materials. In addition, module life-expectancy, once estimated to be one to five years, has been increased to more than ten years. Numerous techniques have been developed to increase the efficiency of cell and module production. Industry has applied these techniques effectively, reducing module production costs approximately five-fold to as low as $550-$750 per square meter. As a result of these advances, the 30-year levelized current year cost of photovoltaic electricity has decreased from an estimated $15.00 per kilowatt-hour in 1975 to approximately $1.50 per kilowatt-hour today.

The U.S. photovoltaic industry has established itself as the world leader, accounting for 58% of the market share in 1982 despite significant advances made by foreign competitors in Japan and the Western European Community. Module shipments by U.S. companies have increased from an estimated 300 kilowatts in 1975 to nearly 5.0 megawatts in 1982. Corresponding increases have been realized in annual production capacity, currently estimated to be 13.1 megawatts.

This briefly summarizes some of the major accomplishments of the PV Program a a whole; I would now like to focus, as requested by the Subcommittee, on the Advance PV Research managed by SERI. There have been significant accomplishments i advanced solar cells in the last five years, including:

1. The achievement of 10% conversion efficiency in several different types of thin-film material cells, including amorphous silicon, copper indium diselenide, cadmium telluride and polycrystalline silicon.
2. The development of stacked multi-junction cells with efficiencies approaching 22%.
3. The demonstration of long-term stability for copper indium diselenide solar cells (over 9,000 hours of constant illumination life testing at temperatures up to 80°C showed no measurable degradation).
4. The measurement of a large (350 $cm^2$) amorphous silicon submodule with an efficiency of 4.4%.
5. The initiation of new amorphous silicon program thrusts intended to revitalize this Nation's effort in a field which the Japanese are now rapidly developing.

Even though the costs of flat-plate silicon modules have continued to decrease and efficiencies increase, it is the thin-film areas, which hold such great promise for low-cost options, that I want to tell you about today. The effort is managed through SERI's Solar Electric Research Division and includes in-house research, device measurement and testing, and research management of numerous subcontracts with industries and universities. The recent development of the National Photovoltaics Program's Five Year Research Plan has served to focus the PV Program on those research areas which hold the most promise for serving as a base for technologies to be developed by industry. Such technologies are expected to compete as viable energy supply alternatives for our Nation if the research goals of the Plan can be achieved; and we believe they can. In formulating these plans the National Program has worked to foster a strong Federal/industry partnership and has also integrated recent analyses done both by the Electric Power Research Institute (EPRI) and DOE's Solar R&D Panel of the Energy Research Advisory Board (ERAB). The three major thrust areas selected for the advanced research component of the PV R&D Program are:

1. Amorphous Thin Films;
2. Polycrystalline Thin Films; and
3. Advanced High Efficiency Concepts.

All hold high promise of meeting or exceeding the established research goals, assuming successful completion of the research paths. A broad-based program was carried out between 1978 and 1983 for a wide range of candidate materials. The progress was quite good as evidenced by the continued improvement in device efficiency as shown in the enclosed graph. Beginning in FY84, well-focused programs have been identified for each of these three major areas. I would now like to tell you about the status and thrusts for these areas.

Amorphous Thin Films. Although 10% efficient small area amorphous silicon solar cells have been reported in both the U.S. and Japan, we have yet to achieve long-term stability and high efficiency for large area cells. In 1983, a competitive research program involving cost sharing with industry was initiated to improve the cell efficiency and stability of single-junction amorphous silicon solar cells. This three-year phased program is designed to demonstrate efficient, large-area submodules of monolithic, intraconnected solar cells and to develop multi-chamber deposition systems to reduce cross contamination between adjacent layers of the cell. The five-year goals of this effort are to demonstrate submodules (1,000 $cm^2$) with efficiencies of 8% and small cells (1 $cm^2$) with efficiencies of 12%.

A closely related program on multi-junction cells was also initiated in 1983 to identify and develop new amorphous silicon alloy materials and new multi-junction cells with the long-term objective of achieving greater than 20% solar cell efficiencies. It is anticipated that the efficiency of the small cells (1 $cm^2$) will reach 18% during the next five years.

The amorphous silicon project is managed by SERI's Amorphous Silicon Research Project Office, recently established by DOE to further improve coordination between

Federal laboratories involved in the National Program and to foster stronger interaction with the private sector.

Polycrystalline Thin Films. The maximum efficiencies achieved for small, laboratory-scale (1 cm$^2$) thin-film cells are 10%-11% and for larger cells (100 cm$^2$), 7.5%. The processes needed for continuous module fabrication could lead to a further reduction in efficiency. Although these efficiencies are lower than for crystalline silicon, by using selected materials they have a long-term potential to yield cell efficiencies as high as 18%.

Several polycrystalline compound semiconductors under investigation have already shown increases in efficiency and improved stability characteristics. For example, a small area (1 cm$^2$) copper indium diselenide ($CuInSe_2$) cell has achieved efficiencies approaching 11% with demonstrated stability under continuous illumination and elevated temperatures for a period exceeding 9,000 hours.

Areas for future investigation in polycrystalline thin films include (1) the mechanisms limiting achievement of efficiencies approaching the theoretical maximums (20% and greater) for $CuInSe_2$, cadmium telluride (CdTe), and zinc phosphide ($Zn_3P_2$), including an understanding of the physical phenomena limiting the fill factor, open circuit voltage, and short circuit current; (2) the use of heterojunctions with these materials to increase efficiency; and (3) the properties of other polycrystalline compounds that might be used to make low-cost cells.

Advanced High Efficiency Concepts. This task supports research on solar cell designs and materials with the objective of achieving the maximum attainable photovoltaic conversion efficiencies. This research is directed toward laboratory demonstrations of solar cells of 35%, or greater, efficiency under concentrated sunlight (approximately 1000x) and thin-film solar cells with one sun efficiencies of 17% to 20% for use in very high efficiency, multi-bandgap, thin-film solar cells. The materials being studied are generally gallium arsenide-based or gallium arsenide-like materials. Although these materials are expected to be more expensive than some of the other thin-film materials, their costs may well be offset by higher efficiencies. As I mentioned earlier, we have achieved a 22% multi-junction cell. Further research is being conducted to (1) identify and resolve mechanisms limiting the performance of materials; (2) identify combinations of materials that yield higher efficiencies; and (3) understand and resolve the interface problems, such as lattice mismatch, which occur when materials are combined in a cascade arrangement.

Certain single crystal materials in this area also show potential for application to thin-film cells. Separated films of gallium arsenide, for example, have demonstrated efficiencies as high as 17% in the laboratory. These materials, with further research, could potentially achieve efficiencies as high as 25%.

Crystalline silicon technology is relatively far along in its development and, as such, is the subject of more limited research tasks. Included in our expected results are (1) an improved understanding of crystalline silicon solar cell physics and design; (2) improved efficiency; (3) improved understanding of the chemistry, physics, structure, and properties of electrically active defects, leading to new approaches and methods to control such defects; and (4) improved understanding of hydrogen passivation, its chemistry/physics, mechanism, and limits of improvement in efficiency.

In each of these areas SERI conducts both in-house research tasks and subcontracted research. In-house we are also continuing to develop, implement, and provide new and state-of-the-art measurement and device capabilities for the improvement of advanced R&D cells and materials, in cooperation with, and in support of subcontracted and internal research activities. SERI supports the DOE decision to request PV capital equipment funds in order to maintain present state-of-the-art capabilities.

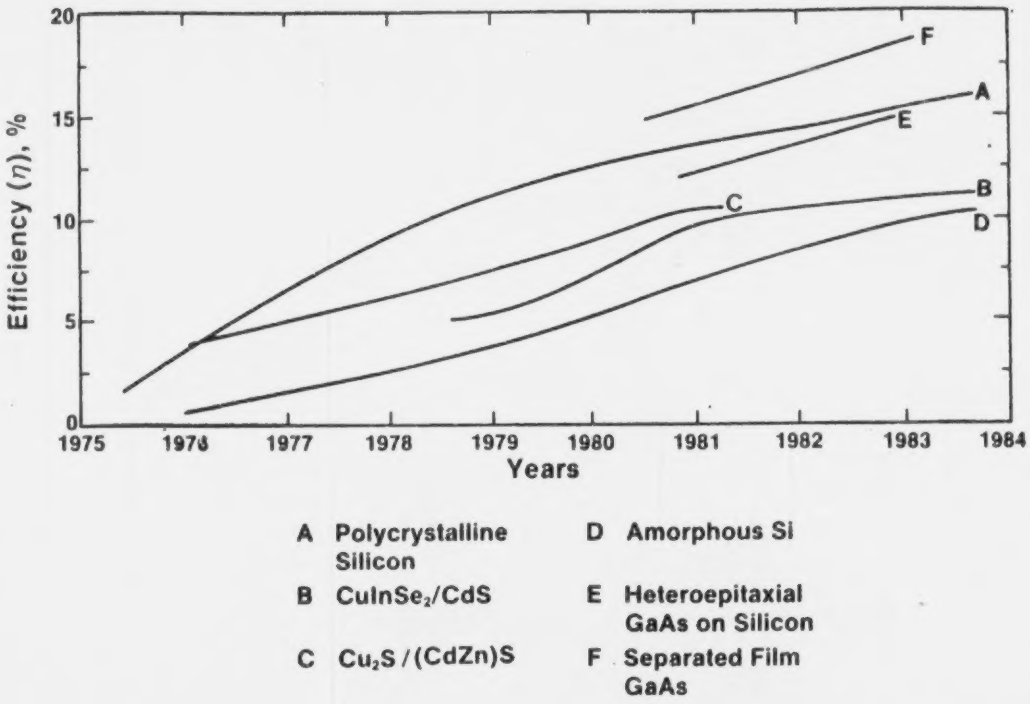
The continued exploration of new concepts and materials is vital to the long-term development of direct solar energy conversion, and the Photovoltaic Program continues to seek methods to solicit innovative ideas from industry (large and small) and universities. At the request of DOE we are developing a new initiative for FY85 for a multi-year, multi-participant grants program to offer basic and applied research funds to qualified universities through a competitive procurement process. The purpose of the proposed grants program is to attract the most qualified university research teams to the National Photovoltaics Program. The initiative would provide continuity of funding over a minimum three-year period which should stimulate universities to build and support inter-disciplinary teams with specialized expertise which can then be applied to further the photovoltaics technology base. Such a program, by its very nature, would support technology transfer to industry by training qualified graduating seniors and graduate students and by publication of research results in the technical literature.

I would also like to take this opportunity to comment on two technology crosscutting areas which contribute not only to the strength of the Photovoltaics Research and Development Program but to SERI's solar research program as a whole. The Insolation and Renewable Resource Assessment Project is one such effort. Over the past several years, this Project has focused on evaluating the effects of the solar spectrum on PV-cell and system performance and their impact on advanced PV cell performance and system requirements. Similar information is also applicable to the development of other solar technology areas.

In photoconversion, which is a broader area also related to photovoltaics, many opportunities exist to develop the use of solar photons as the primary energy source for the production of electricity and certain fuels and, for example, toward improvements in photoelectrochemistry and the dissociation of water to produce hydrogen. Basic research supported by the Basic Energy Sciences (BES) Program of DOE has demonstrated that this is a promising long-term research area.

The National Photovoltaics Program is strong and has achieved significant advancements over the past five years. Efforts during the next five years hold high prospects for equal progress. Thank you for allowing me the opportunity to share my enthusiasm for the progress and potential of the Photovoltaics Research Program and for that portion managed and conducted by SERI. I will be happy to answer any questions from the Subcommittee.

## Cell Efficiency vs. Time



Mrs. **Schneider**. Thank you very much.

Now Dr. Gay from ARCO Solar.

## STATEMENT OF DR. CHARLES GAY, CHAIRMAN, PHOTOVOLTAIC DIVISION, SOLAR ENERGY INDUSTRIES ASSOCIATION

Dr. **Gay**. Madam Chairman, thank you for the opportunity to share my views with you today.

I am Charles Gay. I am chairman of the Photovoltaic Division of the Solar Energy Industries Association. I have consulted with my colleagues throughout the photovoltaic industry, both members of the association and nonmembers, in preparing this testimony. I have worked to make it representative of their views and interests. In all, I have combined the input of 16 major stake-holder groups in preparing the testimony this morning.

For myself, I am vice president of research and development of ARCO Solar.

First let me state my conviction that solar cells as an electric energy supply will succeed and that the world leader in its success will be the United States. We certainly recognize that this is an important export as well as domestic technology.

The United States will lead because we have the ability not only to develop and produce solar cell modules but to use them as well. We have the technical skill, the land, the sunlight, and the demand. We owe our good position in part to nature for the resource, but in greater part to the quality of American science and engineering. Government support and tax incentives, along with the commitment of American industry and support of the American people have bolstered photovoltaics.

We can see this growing strength at the large scale in the SMUD project and a few privately financed powerplants. The SMUD system is exemplary in many ways. It is realistic, having been specified by the user, a utility. It is well planned and technically sound.

One company in the group of companies that I surveyed pointed out that the wide publicity given the bids for the SMUD orders produced, as had the old DOE price goals, a premature public expectation of comparably low prices for small and special product orders.

Overall, however, substantial industry sentiment supports augmentation of the DOE budget to provide full unrestricted funding of the U.S. Government's share of stage III of the SMUD project.

The first private 1-megawatt photovoltaic powerplant delivered power to the Southern California Edison grid in late 1982. Just 1 year later, last year, solar electricity from almost 5 megawatts of a second plant was flowing into the Pacific Gas & Electric Co. grid. These two were the largest in the world in their respective years.

The modular building block design feature of these systems applies to all photovoltaic power systems. Worldwide credibility of photovoltaics has been boosted significantly by these projects. The private powerplants were made economically feasible by the energy investment tax credit, which we consider in this growth period to be essential to the widespread use of solar cells as an electricity source. The credit needs to be enhanced to 30 percent and extended 5 years.

This morning I brought along a few photographs for you to be able to see something of the scale of how photovoltaics is being used today. This is one of our engineers adjacent to a 10-kilowatt, 2-axis tracking system. That type of system is now fully deployed out in Carrisa Plain in central California, with over 750 of these specific units now tracking the sun and delivering electricity to the PG&E grid.

I shall now address the National Photovoltaic Research and Development program. Its greatest single achievement is the high quality, recognized worldwide, of the U.S. commercial solar cell module products. This was accomplished through block purchases of modules from industry between 1975 and 1982, with engineers from the program working very closely with the industry in matters of quality assurance and product specification, doing field testing, failure analysis, and module engineering R&D.

As a result, the industry has been growing strongly, but foreign competition is also strong, especially in the case of some European and all Japanese products. Greater national program achievements lie ahead in the products of the long-term research and development activity currently under way.

The Federal R&D role should continue to be in areas too costly or risky for private industry, such as advanced solar cell technology and new materials.

In addition, this role must include central or common technical areas which are too broad in scope for any individual company to cover. For example, the Department of Energy must continue to pursue the area of performance standards for solar cell modules. If they drop out now, our U.S. standards will be dictated by Europe and Japan.

Another broad area is analyzing and mapping the solar resource. Our excellent existing systems for gathering weather data can provide the input, and the DOE must do the analysis and interpretation.

Industrial health and safety is another broad area of concern and a particular concern of mine. Although solar cell arrays are quite clean in use, large-scale manufacturing must remain equally clean and safe, and there is always work to be done.

Finally, our field is dependent on highly trained specialists, and the Nation must play a role in educating people as our most valuable technical resource.

We are all concerned about technical leadership these days, and I am concerned that the DOE must lead and not follow world trends and innovations in photovoltaic technology. Much of the recent industrial and commercial development of thin-film solar cells owes little to the national photovoltaic program; further, much of it took place outside this country. We have a strong base of expertise in fundamental science, and we must apply it vigorously to thin-film technology and accelerate our efforts on innovative concepts.

As to approach, the DOE must plan and do a few things very well. Their photovoltaic program must be stable, with a long-time horizon and multiyear commitments. Yet at the same time there must be room for flexibility, to anticipate, stimulate, and follow up on new technical discoveries.

The long-term operating plan must be kept alive and updated through serious and comprehensive annual technology reviews covering every national lab and every project area. These reviews must take inputs from both the R&D sector and the industrial/commercial sector, which figure in conclusions and recommendations addressed to updating the plan.

Thank you for the opportunity to be heard today. I will be happy to respond to any questions that you may have.

[The prepared statement of Dr. Gay follows:]

## STATEMENT OF THE PHOTOVOLTAIC DIVISION OF THE SOLAR ENERGY INDUSTRIES ASSOCIATION, DR. CHARLES F. GAY, CHAIRMAN

Mr. Chairman, members, and staff of the subcommittee, thank you for the opportunity to share my views with you today. I am Charles F. Gay, and I am chairman of the Photovoltaic Divison of the Solar Energy Industries Association. I have consulted with my colleagues throughout the photovoltaic industry, both members and non-members of the association, in preparing this testimony, and have worked to make it representative of their views and interests.[1] For myself, I am Vice President for Research and Development of ARCO Solar, Inc., and my biography is attached to this written testimony.

First let me state my conviction that solar cells as an electric energy supply will succeed, and that the world leader in their success will be the United States. We certainly recognize that this is an important export as well as domestic technology.

The U.S. will lead because we have the ability not only to develop and produce solar cell modules but to use them as well. We have the technical skill, the land, the sunlight, and the demand. We owe our good position in part to nature for the resource, but in greater part to the quality of American science and engineering. Government support and tax incentives, along with the commitment of American industry and support from the American people, have bolstered photovoltaics.

We can see this growing strength at the large scale in the SMUD Project and a few privately financed powerplants. The SMUD Project is a powerplant being built by the Sacramento Municipal Utility District in cooperation with the U.S. Department of Energy and the State of California, planned to reach 100 megawatts rated capacity. They are installing their first megawatt of solar cell arrays and are proceeding on the second. This system is exemplary in many ways. It is realistic (having been specified by the user), well-planned, and technically sound. One compnay pointed out that the wide publicity given the bids for the SMUD orders produced, as had the old DOE price goals, a premature public expectation of comparably low prices for small and special product orders. Overall, however, substantial industry sentiment supports augmentation of the DOE budget to provide full unrestricted funding of the U.S. Government share of Stage III of the SMUD Project.

The first private one megawatt photovoltaic powerplant delivered power to the Southern California Edison grid in late 1982. Just a year later, solar electricity from almost five megawatts of a second plant was flowing to the Pacific Gas and Electric Company grid. These two were the largest in the world in their respective years. The modular building block design feature of these systems applies to all photovoltaic power systems. The worldwide credibility of photovoltaics has been boosted significantly by these projects. The private powerplants were made economically feasible by the Energy Investment Tax Credit, which we consider in this growth period to be essential to the widespread use of solar cells as an electricity source. The Credit needs to be enhanced to 30% and extended five years.

Now I will address the National Photovoltaic Research and Development Program. Its greatest single achievement is the high quality, recognized worldwide, of U.S. commercial solar cell module products. This was accomplished through block purchases of modules from industry between 1975 and 1982, with engineers from the Program working very closely with the industry in matters of quality assurance and product specification, doing field testing, failure analysis, and module engineering R&D. As a result the industry has been growing strongly, but foreign competition is also strong, especially in the case of some European and all Japanese products. Greater National Program achievements lie ahead in the products of long-term research and development activity.

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[1] These colleagues include: Howard Morse, Acurex Solar Corp.; Kin Ling, Applied Solar Energy Co.; Bob Campell, Boeing Engineering Co.; Richard Wright, Chronar Corp.; Ed DeMeo, Electric Power Research Institute; Dr. Steve Hudgens, Energy Conversion Devices; Dr. Fritz Wald, Mobil Solar Energy Corp.; Paul Caruso, Solar Power Corp.; Dr. Hal Macomber, Solarex Corp.; Clyde Ragsdale, Solavolt, Inc.; Arthur Rimmer, Solec International, Inc.; Robert Willis, Solenergy Corp.; Roger Little, Spire Corp.; John MacKay, United Energy Corp.; and Don Roberts, Westinghouse Electric Corp.

The Federal R&D role should continue to be in areas too costly or risky for private industry, such as advanced solar cell technology and new materials.

In addition this role must include central or common technical areas which are not too broad in scope for any individual company to cover. For example, the DOE must continue to pursue the area of performance standards for solar cell modules; if they drop out now, our U.S. standards will be dictated by Europe and Japan. Another broad area is analyzing and mapping the solar resource; our excellent existing systems for gathering weather data can provide the input, and the DOE must do the analysis and interpretation.

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As to approach, the DOE must plan and do a few things very well. Their photovoltaic program must be stable, with a long time horizon and multi-year commitments. Yet at the same time there must be room for flexibility, to anticipate, stimulate, and follow up new technical discoveries.

The long term operating plan must be kept alive and updated through serious and comprehensive annual technology reviews covering every National Lab and every project area. These reviews must take inputs from both the R&D sector and the industrial/commercial sector, which figure in conclusions and recommendations addressed to updating the DOE plan.

I will be happy to respond to any questions that you might have.

### CHARLES F. GAY—VICE PRESIDENT FOR RESEARCH AND DEVELOPMENT, ARCO SOLAR, INC.

Dr. Gay manages one of the largest industrial photovoltaic R&D programs in the world. He joined ARCO Solar in 1978 and led the process research, development, and integration work which resulted in establishment of the Company's mass production plant in 1980. He received Atlantic Richfield's Award for Outstanding Technical Achievement in 1981. He presently leads a major research program concerned with thin film solar cell module development.

Dr. Gay was elected Chairman of the Photovoltaic Division of the Solar Energy Industries Association in October of 1983.

He previously served as Research Scientist at Spectrolab, where he developed high-performance aerospace solar cells, culminating in the fabrication of an 18.3% efficient silicon solar cell in 1977.

Dr. Gay earned a Ph.D in Physical Chemistry at the University of California at Riverside. He is the holder of many patents for solar cell designs and processes, and is the author of papers on solar cell and module design, performance, and rating, and on thin-film solar cell technology.

Mrs. SCHNEIDER. I thank you all for your testimony.

I have been asked by other members of this committee to make it possible to include their questions in the record, so at some point in the future, you will probably be getting written questions from some of the other members of the committee.

Let me pick up where you left off, Dr. Gay.

Just so I understand you correctly, are you saying that despite the fact that ARCO has made a major investment in your own project, that you still feel that the Federal Government has a very important role in not only the research aspects of photovoltaic but also a role in creating what might be an artificial market for photovoltaic cells?

Dr. GAY. Yes; that is correct. The key theme that I would like to express and make sure is clearly heard is that research in a laboratory scale is moving along extremely rapidly. Dr. Feucht made some comments directed toward the relative position of some of the technologies that have been sponsored through SERI.

In my personal observation, I have seen values for performance that exceed those in almost all of the areas that Dr. Feucht referred to, the theme here being that the technology is evolving at such a rapid rate that we also need to be sure that the marketplace is ready to accept this new technology.

Mrs. SCHNEIDER. And how is that going to happen?

Dr. GAY. Hopefully, through a coordinated effort between industry, Government, all the remainder of stakeholders that want to see photovoltaics succeed.

I am hoping that we can build a number of bridges between industry and the DOE.

Mrs. SCHNEIDER. I think one of the frustrating elements of the energy discussion that we have witnessed here on this committee has to do with the Synthetic Fuels Corporation, just jumping around to another topic.

Here we have a situation where the Federal Government was involved insofar as providing loan guarantees, financial opportunities, for companies such as ARCO and others to take advantage of for the development of synthetic fuels.

We have $16 billion sitting there right now, and we have no interest in the private sector, it appears, to take advantage of those moneys.

Now, it has been said that the reason is because there is not a market for it, because the price of oil, whether it be foreign or domestic, is as cheap as it is. Now, what are we going to do, through friendly persuasion or what, to maximize the use of our photovoltaic technology and how soon can we expect it to be cost competitive with some of the currently used sources of energy?

Dr. GAY. I expect, as a result of the research that is currently under way, by the end of this decade, we will have modules that are 20 percent efficient, thin-film modules. Those modules will be capable of being used in large-scale systems that can compete with power sources that would also be coming on line in a similar timeframe, the end of this decade.

Mrs. SCHNEIDER. Aren't those modules right now about 11 to 18 percent efficient?

Dr. GAY. Today's commercially available modules are, by and large, made with thick forms of silicon, and those modules range from about 8 to 11 percent efficiency as a module.

The message I was hoping to convey here is that the thin-film technology is moving very rapidly; that we are putting together the pieces of that technology in a form that would let us get to even higher module efficiencies, and we expect that we will be able to achieve significant cost savings because of the degree of raw material reduction that goes into making those modules.

Mrs. SCHNEIDER. Thank you very much.

Mr. Mattimoe, given that there is already a one megawatt utility photovoltaic project on line that is sponsored by Southern California Edison Co., how do you feel that justifies the continued Federal support of the SMUD project?

Mr. MATTIMOE. I believe, Madam Chairman, in that case Southern Cal Edison is not the owner or the builder of the plant. They have contracted for the power that is being supplied from the plant.

In our particular case, we are building a utility quality plant, which I feel is necessary in order to get the utility industry in this Nation to see that photovoltaic can take an important part in meeting their load requirements, particularly their peaking requirements.

Mrs. SCHNEIDER. Dr. Feucht, SERI doesn't really have a permanent home. How serious a problem is that? As you know, there is no money in the fiscal year 1985 budget for the construction of a permanent location for SERI. Do you believe that such a thing is necessary? I hate to put you on the spot, but.

Dr. FEUCHT. Yes, let me comment on that at the moment.

We do have 300 acres that have been donated by the State of Colorado to the U.S. Government, and we are about to complete our first permanent laboratory building. We expect to move into that building in the next 2 to 3 months.

Mrs. SCHNEIDER. Where are those funds coming from in the construction of that?

Dr. FEUCHT. Those funds were allocated, I believe, in the 1982 budget.

Mrs. SCHNEIDER. I see.

Dr. FEUCHT. It was approximately $9 million, which completed a laboratory building which will house about 10 percent of our staff.

Mrs. SCHNEIDER. And what do we do with the other 90 percent?

Dr. FEUCHT. The other 90 percent remain in leased facilities in an office park. We have converted one of those buildings to a laboratory facility. They are well equipped, but the facilities were not really designed for a laboratory, so there are problems both with flexibility, of being able to do the kinds of research work we need to do, and also some safety requirements that make it difficult to use those buildings.

Mrs. SCHNEIDER. So in other words, you are not carrying out the work as efficiently as it could be, given the kind of work environment that you are currently having to work in.

Dr. FEUCHT. That is correct. We have, with the Department, developed a master plan for a second phase and a third phase which would house all the staff on permanent facilities, but of course that depends on future funding.

Mrs. SCHNEIDER. Right.

Well, since SERI was started back in 1977, we have seen its activities and growth to be rather modest, I would say, to say the least, at least from my point of view, and I am just wondering what you foresee as the future for SERI and what might be some of the long-range goals that you are involved in?

Dr. FEUCHT. The growth was quite rapid for about 3 years, and then we went, about 2 years ago, into a decline, so that our staff, which was a total of around 900, has now been reduced to around 540 total.

We do believe, in discussions with the Department, that there will be modest growth out in the future. We believe that the research programs that we are working on, as Charlie indicates in photovoltaics, should provide the technology base that allows industry to achieve highly efficient thin-film cells at a low cost which would make photovoltaics comparable to other energy sources.

Mrs. **Schneider**. Once again, looking for efficiency in Government, I am wondering if you might better be able to accomplish your goals if you were to consolidate some of the programs, research programs, with some of the other national laboratories.

Dr. **Feucht**. We do interact very strongly with the other national laboratories. The Department, of course, has also been looking at the question of whether they should consolidate some activities either at SERI or other labs, and of course we have left that up to the Department at this point.

Mrs. **Schneider**. All right.

Dr. Zwibel, I am just curious to know your overall impressions of the way DOE has been handling the overall management of the photovoltaic program and if you have any specific recommendations as to what can be done to improve it.

I know you focused on systems research and experiments on a small scale, but is there anything else you would like to share with me?

Dr. **Zwibel**. I have been involved in the DOE PV program since 1978, when the intermediate systems experiments started through Sandia.

My impression is that the photovoltaic program has been laid out just wonderfully well. It was structured so that—I am most familiar with the systems experiments. I haven't been involved at all in the basic research. But it has been planned in advance to do those things behind the fence, in an experimental setting, that need to be done, and this has been done very effectively.

You expect to have failures. The intermediate size systems that were part of the 1978 PERDA projects had failures, but the point is, these were experiments and not demonstrations, and one expects to have failures.

I really think that the photovoltaic program has been laid out very intelligently. The only quarrel I have is what their future is for fiscal year 1985 if they cut out systems experiments.

Mrs. **Schneider**. Well, needless to say, that is a concern of many of the members of this committee, that we haven't seen much of a bright future from our perspective insofar as the budqet is concerned for conservation and renewables, but photovoltaic has been fortunate in standing out there and being one element of the solar programs that has received more Federal attention than some of the other programs.

I have every reason to believe that the photovoltaic investment will continue, but I certainly question the investment in some of the other solar areas, nonphotovoltaic.

But once again, I would encourage you to write your Congressman if you want to convey your particular concerns.

I don't have any further questions that I can think of at this time. If there are any other points that you would like to bring to my attention, feel free to do it.

Yes, Dr. Gay?

Dr. **Gay**. I would like to raise one more comment to your question regarding SMUD. The experience that is gained in conducting a 1-megawatt scale system with SMUD is quite a bit different than the experience gained in putting together a 1-megawatt system privately.

We need to learn how to measure performance. We need standards. Standards still have not been given enough emphasis, and it became critical in conducting the first part of SMUD that some actual research went on in figuring out an appropriate standard, and that experiment, you would have hoped, would have had appropriate standards already developed.

Second, we learn a lot about dealing with our end customer and how procurements may be specified. These are a lot of issues which are covered over in the major framework but which come out when you deal with more and more folk who have to interact with each other.

Mrs. **Schneider**. Very good point. Thank you.

Anything else?

[No response.]

Mrs. **Schneider**. Well, I thank you all very much for your testimony and appreciate your help.

The hearing stands adjourned.

[Whereupon, at 12:07 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

[Additional material submitted for the record follows:]

UNITED STATES PHOTOVOLTAICS MANUFACTURERS' AD HOC COMMITTEE
SUITE 900
1101 VERMONT AVENUE, N. W.
WASHINGTON, D. C. 20005
(202) 289-3034

February 29, 1984

The Honorable Don Fuqua
Chairman
House Committee on Science
& Technology
2269 Rayburn House Office Bldg.
Washington, D.C. 20515

Dear Chairman Fuqua:

I am writing on behalf of the U.S. Photovoltaic Manufacturer's Ad Hoc Committee. We support an $18.5 million augmentation of the DOE Budget for the U.S. government's share of Phase III of the Sacramento Municipal Utility District Photovoltaic Project. Phase III will involve construction of 6 megawatts (MW)DC, 5MWAC of photovoltaics in 1986 at a cost, to be shared by the government and SMUD, of not to exceed $40 million.

The Sacramento Municipal Utility District Photovoltaic Project is critical to the timely development of photovoltaics as a utility qualified alternative for electric utility central power station application. SMUD is ideally suited for this project because of the nature of its peak load requirements and its projected high cost of peak power generation. Because of this, SMUD is also ideally suited to follow on to their 6MWDC and complete the remaining portions of the 100MW plant without further federal government subsidy.

Due to declining buy back rates for some utilities in California and the difficulties in enhancing and extending the tax credits, other large scale demonstration projects, such as ARCO Solar's Carissa Plains project with PG&E, are being scaled back. The SMUD project is uniquely positioned to continue forward, help the photovoltaic industry reduce costs, and demonstrate the technology at a scale relevant to utilities.

The industry is supporting this program without regard to whom the winning bidder or bidders might be because of its potential to expand the total market for all of the photovoltaic industry by early demonstration of the technology at the utility scale level.

The first priority of the program should be successful demonstration of utility integrated technology on time and within budget. At $40 million, Phase III of the SMUD Project represents substantial continued cost reduction of both photovoltaic devices and balance of systems. The Sacramento Municipal Utility District should have adequate authority and discretion to administer the project so as to achieve these objectives and thereby maximize the probability of its success with the proposed unsubsidized follow on segments.

The U.S. government has spent over $750 million on research and development of photovoltaic technology. Presumably, these funds were spent to help create a viable technology and U.S. industry capable of producing material quantities of secure, clean electricity. This increment of $18.5 million is critical to the successful completion of that undertaking.

Sincerely,

Cynthia C. Lebow

Cynthia C. Lebow
Counsel for the United States
Photovoltaics Manufacturers'
Ad Hoc Committee

On behalf of:

Arco Solar, Inc.
Energy Conversion Devices
Mobil Solar Energy Corporation
Solarex Corporation
Spire Corporation

# FISCAL YEAR 1985
# DEPARTMENT OF ENERGY
# AUTHORIZATION

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## THURSDAY, MARCH 1, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Development and Application,
*Washington, DC.*

The subcommittee met, pursuant to adjournment, at 9:30 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the committee) presiding.

Present: Representatives Fuqua, Harkin, Sensenbrenner, Schneider, Bateman, Lewis, and Carney.

Staff present: Eugene Frankel, science consultant; Robert Kripowicz, staff director; Bill Harvey, minority energy coordinator; Dan Steinway, minority counsel; and John Ratzel, minority counsel.

Mr. Fuqua. The subcommittee will be in order.

We complete the hearings today on the fiscal year 1985 authorization request for conservation and renewable energy.

We are very heartened by the progress we have made in solar thermal, particularly with the Barstow or Solar I plant but I am seriously concerned that there appears not to be any follow-on activity. Two industry teams have proposed to build privately financed central receiver systems, using advanced and somewhat untested technology—liquid sodium and molten salt—and we are concerned that DOE has not requested any funds in 1985 to support research on some of the high-risk components involved.

We understand in the geothermal area that there was a recent experiment in New Mexico that produced an enormous fracture, with more than 100 megawatts of capacity. Here, again, it appears that DOE will need more funds than they requested to complete the circulation loop and extract heat from the fracture. We are also concerned that DOE may not have requested sufficient funds to operate its two design wells and acquire a new well of opportunity in the geopressured geothermal program.

In the building program, DOE appears again to be unwilling to fund research related to whole buildings as systems, passive solar, or combustion and refrigeration equipment. It has also, once again, requested no funds for the energy extension service, despite several major new initiatives in technology transfer.

We will examine, in our second panel, the likely consequences of the budget reductions proposed in these areas.

The first panel today is Mr. Frank Duquette, with the Solar Thermal Division of McDonnell Douglas, and he is accompanied by Tom Springer. Then we have Mr. Fred Goldsberry, who is the chief engineer of Zapata Exploration Co. in Texas, and John T. Whetten, Earth and Space Sciences Division of the Los Alamos National Lab.

Frank, we are pleased to have you here this morning, and maybe you might tell us a little bit about solar and where we are going.

[The opening statements of Mr. Bateman and Mr. Winn follow:]

### OPENING STATEMENT BY HON. LARRY WINN, JR.

Thank you Mr. Chairman for this opportunity to welcome our witnesses. This is the third and final hearing on conservation, solar, and renewable energy programs relating to the fiscal year 1985 DOE Authorization request. I am certain that the information provided to us today will be as beneficial as our previous hearings have proved to be.

The Science and Technology Committee has been very supportive of the conservation and renewable energy programs in the past decade. In fact, I think we have been very generous in providing funds in basic research, applied research, proof-of-concept projects, pilot plants and demonstration plants. Unfortunately, our present and anticipated budget problems do not allow us to participate to the extent that we have in the past. Therefore, we have taken a very prudent approach. We have decided to fund basic and applied research on the basis that industry could not justify expenditures for such long-term, high-risk investigations.

With the successful completion of basic and applied research projects, including proof-of-concept activities, the area of investigation has been moved to a short-term, lower-risk environment. At this stage we would rightly expect industry to become involved and to carry a greater or even the total share of further investigation, including pilot plant and demonstration plant activities. In this manner the Federal sponsorship occurs at the inception and it phases into industry's participation.

I continue to support this research and development approach. Within that approach, I also encourage the Department of Energy to be both creative and innovative. In this regard, if any breakthroughs or reevaluations have occurred since the fiscal year 1985 budget request was submitted, I would be glad to work with DOE if they should want to redefine priorities. In any case I am very pleased with the funding level requested by the administration and believe it carries these programs forward through fiscal year 1985 very effectively. I see no reason that we should increase the amount of funds requested by DOE.

Again, Mr. Chairman, thank you for holding this hearing today. It should continue to benefit our committee.

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### OPENING STATEMENT OF HON. HERBERT H. BATEMAN

Today's hearing is the third in a series of hearings on the Department of Energy's fiscal year 1985 budget request for its conservation and renewable energy programs. Our past 2 days of hearings have been extremely helpful in helping our subcommittee review the Department's budget for 1985. I am sure today will prove just as helpful.

It is encouraging to see the Department has recommended a healthy increase in these areas over its fiscal year 1984 levels. These programs can play a vital role in helping our Nation move forward in developing an effective energy policy for the future. Failing to develop a national energy policy that takes advantage of the potential of our renewable energy resources, as well as the benefits of energy conservation, would be indeed remiss.

## STATEMENT OF FRANK DUQUETTE, CHAIRMAN, SOLAR THERMAL DIVISION—SEIA, McDONNELL DOUGLAS ASTRONAUTICS CO., HUNTINGTON BEACH, CA; ACCOMPANIED BY TOM SPRINGER, ENERGY SYSTEMS GROUP, ROCKWELL INTERNATIONAL CORP., CANOGA PARK, CA, AND LYNN GLOVER, McDONNELL DOUGLAS

Mr. DUQUETTE. Thank you very much, Mr. Chairman.

My testimony will be submitted on behalf of the Solar Thermal Division, a component of the Solar Energy Industries Association.

Mr. FUQUA. If I could interrupt you just a minute, Frank. All of the witnesses, if you have prepared statements, you can submit them for the record and then summarize in whatever fashion.

Mr. DUQUETTE. I would like to make that request. We do have a prepared statement, and I would appreciate that being put in the record. I will attempt to be as brief as possible.

You probably recall that our membership is made up of large multinational energy firms, as well as aerospace companies and small, entrepreneurial innovative groups. We have been at the forefront of developing this technology in solar thermal for the past 10 years, in concert with Government-supported programs. We feel that we have developed and maintained world leadership, and we would like to continue with bringing the technology into the marketplace.

On behalf of the member companies and my associates here, both Mr. Springer, whom you mentioned, and Mr. Glover, who is the program manager for the Solar 100 project from McDonnell Douglas, I would like to thank you for this opportunity again to review the fiscal year 1985 DOE budget request. We have a few comments on that.

I would like to say that we are pleased to see that the level of effort certainly has exceeded past years, particularly with regard to this administration's direction for renewable energy development.

We want to thank this subcommittee for their foresight and support in bringing about that kind of effort that we hope will lead to near-term high-payoff technology utilization in the marketplace; This is for solar thermal technology, the central receivers, parabolic dishes, blind focus parabolic troughs.

With regard to a related issue, Mr. Chairman, we thank you and applaud your efforts for supporting the extension of energy investment tax credits. This is a very appropriate role, we feel, for Government support and one that is vitally needed to bring us over the hurdles necessary again for commercial market acceptance, at least for the next 8 to 10 years.

Our statement will outline quickly past accomplishments we will talk a little bit about technology readiness and market acceptance. And then finally we will detail the industry's version of a fiscal year 1985 technology budget that I think meets the objectives of this committee and certainly industry and in concert with the DOE to bring portions of the technology into the private sector.

We view the administration's 1985 budget request with some concern because we think it is too heavily directed toward the long-term research arena. We agree that we need to continue this long-term research, but on the other hand we also feel that we should complete the ongoing and current levels of technology, such that we can get the payoff in the utilization of the technology for this rather clean, unencumbered, and what we think can be economically viable solar option.

I guess we sort of look at it this way. Really, what good is continuing with the far-out effort if the near-term work that the Government and industry have financed to the tune of over $600 million in the last 10 years, in DOE, in ERDA, and even National Science Foundation-related programs is not brought to a point where it can really move into the private sector. I guess the thrust of our budget recommendation to this committee probably will be one that agrees on one hand and supports the longer term technology but requests additional effort in the subsystem component and large-scale experiment area that can bring us over into completing the work that is needed for the private sector to take over.

As I mentioned, a number of these companies have been working with the technology for many years. We are very interested in bringing about meeting the final objectives of commercialization. We have not been in a position where there has been a great amount of return on corporate investment, however we are willing to hang in there. We want to hang in and complete the job and do it kind of in partnership with the DOE program.

I think that what we are talking about here is a technology that has a great deal of interest in the user sector. A number of utility and power companies in the Southwestern United States have either participated directly or have included in their future power generation plans some of these technology options, in particular the central receiver option, which can provide large amounts of bulk electricity to the electric grids of these utilities. Southern California Edison, for instance, Pacific Gas and Electric, Arizona Public Service, and a number of others are active and very interested in utilizing the central receiver concept.

One year ago, our industry group represented before this committee that we thought we could complete the engineering level and system level work within a 3-year period, such that we would be able to move away for Government budget outlay support. We thought that our reasons at that time were fairly sound, and we were working along those lines. However, the assessments that we made at that time really have not come about in the past year. We were believing that oil prices would increase rather than decrease. In fact, they have stabilized at historically low levels and are forecasted to stay there for maybe several years. That forecast can be controversial, and we will not take any time to discuss it further here.

Funding for DOE-supported solar thermal activities at a higher level than Congress finally approved was something we had expected. We were looking for the final enactment of legislation that would increase energy investment tax credits out to 1990 or 1992, with an enhancement to perhaps as high as 25 percent.

If you add to these negative factors other things that have happened in the world during this past year, the congressional action rescinded the accelerated writeoff schedules, pursuant to the accelerated cost recovery system. Also, the basis adjustment provision greatly diluted the value of the existing energy tax credit. So a number of these things happened and kind of changed the world a little bit, and certainly our assessment, which probably made some sense at that time, needs to be changed. For that reason, we are saying certainly there is a continuing need for an industry-DOE partnership for several more years anyway.

I do not think it is necessary to talk about a summary of the development of the technology. We have had many more successful events during the past year. Solar I is continuing to operate and is readying itself for a utility power production phase. We have a repowering project on the boards now for a detailed design that we will hear about from Mr. Springer a little bit later. That is a PG&E project also with Rockwell. We have Arizona Public Service that is interested in continuing with their Saguaro repowering design at 60 megawatts, and we have Southern California Edison that has been working with an industry team to bring into being the first commercial-sized 100-megawatt central receiver plant.

Parabolic troughs have really moved to the private sector, but they do need the tax credit support just like all the rest of our technologies do. Parabolic dish work is being tested successfully in the field, and as I mentioned, the central receiver area is one in which large-scale experiments will be needed to carry us into this next commercial phase.

There are many other accomplishments that I could enumerate, but they are covered in the written testimony, and I will not take too much more of your time to cover them.

Finally, I want to address our budget structure, tell you a little bit about it, and then request that perhaps you also look at the written testimony, where there is much more detailed line-item backup. Our budget totals $54.7 million. This level is slightly over $17 million above the administration's request for 1985. It includes funding $14 million for research and development activities for the total spectrum of the technology, in supporting as well as exploratory research. We certainly think that is an important area to continue.

We have $27 million earmarked for central receiver R&D, and this level includes system and subsystem and component development for both molten salt and sodium systems. This is really base technology that we have been talking about having needed to be completed for the past 2 or 3 years and really have not been able to get it off the ground, although the molten salt electric experiment in category B for repowering will help.

There is about $10.7 million in that particular central receiver slice for what we call direct support of large-scale experiments in central receivers. We feel that there are one or more projects that are greatly in need of this kind of support that will help get them over the hurdle to a satisfactory completion and payoff in the private sector.

There is $12 million for parabolic dish component development work, and $1.7 million for planning and program support. That pretty much outlines our approach for the budget. I think I can summarize or finalize by saying that we. are seeing the dividends for this technology beginning to pay off. No other renewable technology has met with more technical success, given the technical complexity. With your support, we can continue with the Government-industry relationship that we think is working very well and get on with the job and get it finished to the benefit of the country.

Thank you very much.

[The prepared statement of Mr. Duquette follows:]

# SOLAR THERMAL DIVISION

## CHAIRMAN, FRANK F. DUQUETTE

## CONGRESSIONAL TESTIMONY

## 1 MARCH 1984

## ORAL PRESENTATION

Mr. Chairman,

My testimony is submitted on behalf of the Solar Thermal Division, a component of the Solar Energy Industries Association (SEIA). Ranging in size from large, multinational energy and aerospace corporations to small, innovative entrepreneurial firms, our members have constantly been at the forefront of solar thermal technology, and, as a result, the United States now enjoys the position of world leader in this technology. This leadership is based upon the momentum gained throughout the 1970's, beginning with the early efforts of the National Science Foundation Solar Technology Program and continuing thereafter with the support of the DOE and its predecessor, ERDA. Over ten years of cooperative effort in the federally supported program have led to the development of advanced system designs that have exceeded nearly all performance expectations. The transition from early proof of concept experiments and test prototypes to full scale operating systems for industrial and utility users is almost a reality.

On behalf of the member companies, I wish to thank the committee for this opportunity to present the industry's views on the FY '85 budget pertaining to Federally funded solar thermal technologies.

Also, we particularly wish to thank this subcommittee and staff for its foresight and ongoing efforts to support and bring along those elements of the solar program that have near term, high payoff potential. With regard to a related issue, we very much appreciate and applaud the Chairman's leadership in proposing an extension beyond 1985 of the Federal Energy Investment Tax Credits which represent an appropriate role for the Government in enhancing the state of this emerging energy technology industry.

Our statement outlines:

- Past accomplishments of the Government/Industry partnership and the need for a moderate level of continuing Government support to achieve timely technology transfer to the private sector for a multiplicity of applications.
- Technology readiness and market acceptance, financial barriers to technology utilization, potential oil displacement, other Government financial support options and related benefits.
- A detailed FY '85 budget summary and brief discussion of those budget items which we recommend for consideration by this Committee.

We view with some concern, the thrust of the Administration's FY '85 budget request. In our view, it is directed too heavily along the line of longterm research and development. The nearer term technology at this stage of development, still requires federal support to reduce technical risk and validate commercial or near commercial applications. Private industry is unable to assume the entire burden of completing the R&D tasks remaining for this current generation of technologies.

We urge Congress to again re-direct the emphasis of DOE's program to include a balance between near and far term objectives. We are recommending an additional budget line item to support a three year authorization of one or more cost-shared large scale experiment(s) of commercial or near commercial-sized central receiver hardware.

If the private sector is unable to shoulder the entire cost of developing the higher risk, near-term R&D tasks remaining before commercialization then there appears to be little value in focusing government efforts on longterm, high risk research endeavors. The bridge to the longer term R&D needs cannot possibly be built if DOE and the Congress intend to rely on industry alone. Continuing Government support in the form of tax incentives, loan guarantees and budget outlays is needed.

Last year the solar thermal industry represented before this Committee that no more than three years of additional direct support of the major solar thermal technologies would be required in order to complete DOE's program for base technology and system level engineering. We believe this was a reasonable assessment at that time based upon a series of assumptions which did not or have yet to materialize. These assumptions were:

- An increase in oil prices rather than the current stabilization of those prices at historically low levels;
- Funding for DOE supported solar thermal activities at a higher level than Congress finally approved;
- Enactment of legislation to extend to 1992 and increase to twenty-five percent (25%) energy tax credits for qualifying solar energy property.

Add to these negative factors prior year Congressional action (TEFRA of 1982) in rescinding the more favorable 1985 and 1986 writeoff schedules pursuant to the accelerated cost recovery system (ACRS) and the enactment of the "basis adjustment" provision which greatly diluted the value of the energy tax credit. These various events have created a less than favorable climate in which industry could be expected to meet financial hurdles to move solar thermal technologies.

The climate has changed. We believe that last year's assessment of industry's efforts to commercialize solar thermal technologies must now be moderated because we must add to the technical risk and the high front-end capital requirement of these systems, a continued uncertain economic environment, a world energy picture which forecasts prices at continuing low levels, and a series of tax changes which rescinded previously enacted tax incentives.

The recommendations put forward in this statement recognize these changes and the fact that industry still requires a DOE partnership.

## TECHNOLOGY SUMMARY

The solar thermal industry recommends that the major thrust of the government/industry effort in the solar thermal program should be to establish a capability in the private sector to deliver technically proven, cost-effective thermal systems for converting sunlight to low-, medium-, and high-temperature heat for a broad range of process heat and electric power applications. This thrust, I believe, is totally consistent with the prior year objectives of this Committee.

The technical feasibility of concentrating solar thermal systems has been established by a combination of government and industry supported efforts during the past decade. The federal/industry investment alone has reached a level of over 600 million dollars. The resulting cost of solar thermal energy hardware has dropped significantly in the years since the inception of the program.

The following design basic concepts are continuing development under this program. These design concepts are:

- Central Receiver Systems
- Parabolic Trough Systems
- Parabolic Dish Systems

Hemispherical bowl and solar pond technologies are either in the private sector or they have been phased out of the program.

Parabolic trough technology is being successfully transferred into the commercial marketplace but this technology, like other solar thermal technologies, continues to depend on tax credits to meet financial hurdles.

Parabolic dish prototype hardware R&D&D is currently being successfully conducted in the field. With respect to central receiver systems, recent experience with test facilities and operating system experiments has demonstrated equipment reliability and durability for heliostat systems which is consistent with market demands for specific applications. Government support for large scale system and subsystem experiments, along with mass production of these types of heliostats which the Federal R&D effort has developed will reduce near term system costs to acceptable levels and will generate the production levels needed to achieve stated cost goals in the 19902000 period.

## MARKET ASSESSMENT

Let me concentrate on the solar thermal central receiver program which industry believes is nearing the point of being passed from government to the private sector. The research and development and proof of concept experiments have proven this technology to be technologically sound and environmentally safe.

This technology has not yet reached the stage in its development where it can be continued and completed by private capital alone. However, it is capable of being economically competitive and can help to stabilize and lower the cost of electricity for the ratepayer in the next decade. Utilities and power companies believe that this technology has the potential for being an important source of power generation for future generating capacity. However, the additional amount of development needed to ensure acceptance by utilities and other industries will not take place without shared federal assistance.

Generating capacity for the 1990 time frame and beyond is presently a part of utility planning activities. Several utilities, including Southern California Edison, Arizona Public Service Company and Pacific Gas and Electric, are planning for central receiver power plants in their power generation forecasts for the following reasons:

> Solar can be used for providing short-term intermediate capacity and quasi baseload operation that has previously been served by oil and gas. This capacity will be provided in the form of repowering existing oil and gas fired units (post 1986 operations) and as stand-alone plants.
>
> Smaller capacity additions on the order of 50-100 megawatts electric (MWe) are particularly suited to utility needs and avoid the problems of long licensing and permitting requirements and the longer construction times associated with other types of projects, as well as more attractive capital funding options.

Integration and operation of central receiver power plants fit well into utility generation systems. The central receiver technology adapts reasonably well with conventionally fueled thermal electric generating technology, with which utilities are familiar and have extensive operating experience.

Since a renewable energy source - the sun - is used, these units, once the cost of construction is in place, offer protection against escalating fuel and transportation costs -- issues of great importance to stabilizing utility rates for the customers of electric utilities.

Industry studies indicate a potential market of ~~between~~ AS MANY AS 30 ~~50-80~~ solar thermal central receiver plants ~~to be~~ THAT COULD BE constructed in the southwestern U.S. by the year 2002. If built, these environmentally benign plants would displace more than 24 ~~60~~ million barrels of oil per year. Additional oil displacement could be achieved for solar industrial process heat applications, including steam for enhance oil recovery.

## SIGNIFICANT ACCOMPLISHMENTS

Significant progress continues for the development of solar central receivers technology and applications:

1) Solar One the 10 MWe pilot plant is generating valuable performance and operating data since turbine roll in April 1982 and is being readied for the

utility power production phase. As of mid-February 1984, 6,833,400 Kwh of energy have been produced.

2) An industry team was selected and is performing detailed design for a 30 MW grid repowering project with government cost sharing.
3) The small scale molten salt electric experiment (MSEE) is operating at the government's central receiver test facility (CRTF) in Albuquerque.
4) The ARCO Solar 1 MW enhanced oil recovery (EOR) system is operating in the California oil fields and meeting performance goals.
5) Arizona Public Service is continuing efforts to develop the 60 MW Saguaro repowering project.
6) Southern California Edison has joined with industry to further develop the project structure for Solar 100, the first commercial sized central receiver power plant at 100 MWe.

The PG&E/Rockwell/ARCO/Bechtel 30 MWe sodium cooled receiver design was selected for a cost-shared detail design effort, leading to a follow-on phase hardware operational plant in late 1986. This design effort is currently underway.

Southern California Edison has given considerable incentive to industry for commercial development of central receiver technology through that utility's Solar 100 solicitation. Four companies responded to the Edison request to participate in a conceptual engineering study for a 100 MWe commercial plant. Late last year, Edison selected the McDonnell Douglas design approach utilizing a two module molten salt system. This user/designer team is currently developing a project structure which is targeted to be operational in the 1988-1989 time period.

The Parabolic Dish Stirling Cooperative Agreement completed its design and fabrication phases. It is presently operating daily at Rancho Mirage, California and has achieved electrical outputs of 22.8 KW for a conversion efficiency of sunlight to electricity of 28.9%.

The Organic Rankine engine successfully completed 100 hours of simulated onsun operations in the labroatory. The sub atmospheric brayton module achieved system checkout and integration, and the instrumentation and controls were developed during this past year.

U.S./Sweden industrial firms have consummated a cooperative agreement for the development and world marketing of commercial scale Dish Stirling concentrators (25KWe).

An American Solar King 60,000 ft$^2$ commercial IPH parabolic trough line focus system is in operation for the Gould Corporation's process plant in Arizona.

Heavy effort to develop private sector financing for commercial parabolic trough projects is continuing.

MISR trough systems in operation at the Sandia-Albuquerque and SERI are providing valuable test data and operating experience.

We respectfully request the subcommittee's full support.

Thank you very much.

We can see the dividends for this technology beginning to pay off. We know of no other renewable energy program that has met with more technical success, given the magnitude of technical complexity. The Government/industry partnership is working.

Finally, Mr. Chairman, let me briefly summarize our specific budget recommendations for FY 1985 which are supported by the preceeding discussion:

The attached budget totals 54.7 million. This level is slightly over 17 million more than the Administration's request for FY 1985. This increase, along with 15 million/year continuing into FY '86 and FY '87, provides for near-term emphasis on needed development and support for one or more large scale experiments needed to bring central reeiver technology into a final stage of commercial market acceptance. A more detailed line item description is included with this statement.

We think that this budget recommendation at 54.7 million outlines a reasonably balanced program for FY '85 which builds upon the Administration's program and provides additional emphasis on nearer term subsystem/component development and support for large scale experiments. Furthermore, it recognizes the need to reduce federal budget levels, with a minimum of out year carry-over and yet maintains the momentum of a viable technology in which a substantial investment by the Government has already been made.

FINAL
2/24/84

SEIA SOLAR THERMAL DIVISION
FY 85 TECHNOLOGY BUDGET RECOMMENDATIONS

| | | | | |
|---|---|---|---|---|
| A. RESEARCH | | | | 13.9 |
| 1. EXPLORATORY | | | | |
| a) Materials | | 3.3 | | |
| b) Innovative Concepts (PRDA - New & Follow-on) | | 1.0 | | |
| c) University Thermal Research | | 1.7 | | |
| d) Photo/Thermal Chemical | | .7 | | |
| 2. SUPPORTING | | | | |
| a) Innovative Collectors, Concentrators and Refractive Devices | | 2.0 | | |
| b) Parabolic Trough Materials | | 0.5 | | |
| c) Parabolic Dish Materials, Controls & Thermal Storage | | 1.8 | | |
| d) Fuels & Chemicals (Hi-Temp Receiver/Reactor 1500°F-2500°F) | | 2.9 | | |
| B. CENTRAL RECEIVER RESEARCH & DEVELOPMENT | | | | 26.7 |
| 1. SUBSYSTEM/COMPONENT DEVELOPMENT | | | 8.9 | |
| a) CRTF Operations | | 1.4 | | |
| b) Subsystem Component Development<br>-2nd Generation Receiver<br>-Steam Generator, Storage | | 6.5 | | |
| c) Automated, Unattended Control System | | 1.0 | | |
| 2. EXPERIMENTS | | | 17.8 | |
| a) Solar I | | | | |
| -O&M | | 3.6 | | |
| -Performance Analysis & Test | | 1.0 | | |
| b) MSEE Operations & Test | | 2.4 | | |
| c) Large Scale Experiments<br>-Direct support of one or more industrial team projects | | 10.3 | | |
| d) Small, Remote System Concepts | | 0.5 | | |
| C. DISTRIBUTED COLLECTOR TECHNOLOGY DEVELOPMENT | | | | 12.4 |
| 1. PARABOLIC DISH | | | 11.9 | |
| a) Test Facilities | | 1.5 | | |
| b) Thermal Transport | | 1.7 | | |
| c) Dish Electric | | 4.2 | | |
| -Brayton | 2.5 | | | |
| -Free Piston Stirling | 1.7 | | | |
| d) Adv. Concentrator | | 3.0 | | |
| e) Small Community System Experiment | | 1.0 | | |
| f) Capital Equipment | | 0.5 | | |
| 2. PARABOLIC TROUGH - Operation, Refurbishment & Performance Data | | | 0.5 | |
| D. PLANNING AND PROGRAM SUPPORT | | | | 1.7 |
| TOTAL | | | | 54.7 |

## 5.0 PROPOSED FY 85 BUDGET

## SEIA SOLAR THERMAL DIVISION
## FY 85 TECHNOLOGY BUDGET RECOMMENDATIONS

### A. RESEARCH

#### 1. EXPLORATORY

a) Materials. An amount of $3.3 mil is recommended for work in the following areas: Reflective surfaces (glass, plastic, acrylic coatings, etc.); anti-reflective, selective and absorptive coatings; seals; improved glass (thin, strength); high temperature, flexible hoses; structural materials (weight, price, strength, cycle life); ceramics; transparent windows; cavity insulation and shielding at operating temperatures; insulation for high-flux systems (1.5 $MW/m^2$ to 2.0 $MW/m^2$); corrosion-resistant properties of low-cost materials for nitrate salts; and measurements of physical properties of nitrate salts.

b) Innovative Concepts (PRDA - New and Follow-on)

An amount of $0.5 mil is recommended for solicited innovative research. It is recommended that evaluation of the PRDA responses be carried out or monitored by a peer review committee incorporating a majority of university researchers. This will both assure the high quality of the research undertaken and assure that the research is outside the area of immediate problem solving. It is also recommended that $0.5 mil be made available for two to three follow-on experiments (Phase II) selected from the present innovative research contracts.

### c) University Thermal Research

The expansion of the solar thermal technology base for cost effective approaches to future commercial market applications requires continuity of research direction and funding. In the view of industry, the research program should be addressing the needs related to performance improvement, cost reduction of critical subsystems (collectors, receivers, etc.) and expansion into new applications such as fuels and chemicals. The research should emphasize the removal of technical barriers prior to engineering development by industry.

Research work carried out by U.S. universities continues to be useful in identifying promising concepts and processes in solar thermal technology and transitioning technology to private industry. It is recommended to continue funding for the ongoing Solar Thermal Advanced Research Activity Center (STARC) at the University of Houston (UH) at $0.7 mil and at GIT at $1.0 mil. The GIT funding level recognizes the presence of the Advanced Components Test Facility (ACTF) at GIT and includes $0.25 mil to maintain it in an operational status.

### d) Photo/Thermal Chemical

$0.7 mil is recommended for basic research of photochemical effects of high flux and high temperatures for various atmospheres. This work is needed to better understand degradation of receiver surface materials, both for external and direct flux particle receivers.

2. SUPPORTING

a) Innovative Collectors, Concentrators and Refractive Devices

Reflector materials development for low cost, lightweight concentrators. The program includes research and small scale experiments to develop silvered polymeric reflectors having 92% reflectance, 15 year life, and resistance to ultraviolet and environmental attack. The program will also include research to establish the feasibility of polymer materials for structural membranes with an emphasis on creep fatigue, durability under wind and hail impact, ease of handling and attachment, optical quality, stability and weatherability ($1,950,000).

b) Parabolic Trough Materials

A funding level of $0.5 mil is provided to support continuing generic R&D for components and materials which will provide higher performance, lower capital costs and longer lifetime for trough hardware. A priority need is for lower cost, 20-year life, relfective services with greater than 96% reflectivity, and high production volume cost of $1.50/ft$^2$ or better. Other important areas include high temperature heat transfer fluids; higher emmissivity, long life, absorptive coatings for receivers; long life, stable evacuated tube receivers.

c) Parabolic Dish Materials, Controls and Thermal Storage

The materials and component research program shall support the parabolic dish technology by providing $1.8 mil towards heat pipe/thermal storage receivers, application of fiber optics for dish controls and reflective surface material development for compound curvature applications.

d) Fuels and Chemicals

Thermo chemical and high temperature receiver/reactor ($1500^{\circ}F-2500^{\circ}F$) concepts definition and development. Although the solar thermal industry recommends that R&D in the area of the application of solar thermal processes to the production of fuels and chemicals be continued, we do not feel that it should have a high priority since it cannot have a near-term impact on stabilization of energy prices or on energy independence. We do feel, however, that a $2.9 mil effort is justified, provided it is expended on research of processes and systems that can potentially apply to a broad range of current industrial processes and with increased chemical industry participation. Direct flux particle receivers need basic/exploratory research as well as development. Even though, for example, a long-term goal of producing hydrogen by means of thermochemical processes appears to be promising, that goal should be reached via analyses, research, and development which can be of use to the U.S. industry in the near term. The industry feels that funding for research and development in the field of fuels and chemicals should be kept at a relatively low level until the nearer-term technology development applying to the parabolic dish and central receivers is at a stage at which it can and will be picked up by the private sector for commercialization. Out-year budgets for fuels and chemicals are, therefore, recommended for increases consistent with the potential impact they can have on the longer term energy supply for the U.S.

## B. CENTRAL RECEIVER RESEARCH & DEVELOPMENT

### 1. SUBSYSTEM/COMPONENT DEVELOPMENT

#### a) CRTF Operations

The CRTF continues to be a valuable research tool for central receiver development. The ability to transfer the solar central receiver technology to the private sector at any time will depend to some extent on the degree to which the technical feasibility of the process or the performance of a component has been verified at a real solar source. In addition, private industry anticipates a need to have facilities available (much like those available for high energy physics or nuclear research) at which testing can be conducted on hardware designed and fabricated by private industry. Any given private organization could not afford or justify keeping a facility active on the basis of the infrequent times at which its own needs must be met. Industry feels, therefore, that this need should be logically and properly met by federal involvement. A budget of $1.4 mil is recommended for FY 1985, and similar budgets are required for out-years for this facility.

#### b) Subsystem/Component Development

One of the major barriers that impedes the ability of industry to pick up the central receiver technology is the high cost and high risk associated with the development of certain key central receiver components. Principally, these components are the receiver, the steam generator, and storage. In order to reduce the perceived risk of these components to the point at which the private sector can pick them up and complete the development for commercialization, the industry recommends a base technology development effort which includes the receiver as well as the other two key components, for both molten salt and sodium systems.

Recommendations for molten salt work are as follows:

Extended Receiver Test, CRTF: $0.5 mil. Twelve month extended lifetime and performance testing of Category B 5 $MW_t$ model molten salt receiver.

Continued development of operating strategies including overnight drain-down vs warm stand-by, transient responses, and reduction of thermal cycling effects. Extended testing and experience with heat tracing and salt line instrumentation.

Extended Pump and Valve Test, CRTF: $0.8 mil. Twelve month extended full-scale molten salt pump and valve testing for performance and reliability. Data to be collected under both hot (1050°F) and cold (530°F) conditions. If only the hot (or cold) loop tests are conducted under Category B, then the corresponding cold (or hot) loop tests must be conducted here. Extended testing and experience with heat tracing and salt line instrumentation.

Storage Tank Thermal Cycling: $1.1 mil. New experiments with molten salt storage tanks to test a scale version of the preferred full-scale design for resistance to thermal cycling and for leak detection methods.

Physical Property Test, Cover Gas and Metals Corrosion: $0.3 mil. Extended monitoring of molten salt properties, including the addition of additives for lowering the melting point and raising the operating temperatures, the evaluation of several cover gases in storage tanks and continued and expanded operation of the molten salt corrosion test loops at CRTF. Dismantling and inspection of MSEE molten salt steam generator for abnormal corrosion effects.

Liquid Sodium Recommendations Follow:

> Reheater, $1.0 mil. While sodium-to-water steam generators have been developed for the evaporator and superheater mode of operation, operation in the reheater mode is sufficiently different so that development and testing is required. There are no U.S. manufacturers of steam generators which operate in this mode. The use of reheat will allow a significant improvement in turbine efficiency for solar systems and will allow them to be more competitive with fossil-fired plants. This development activity would include the design and analysis of plant sized reheater units for operation at 1100°F sodium temperature followed by the fabrication and test of a prototype test unit.
>
> 2nd Generation Receiver, $1.0 mil. A second generation receiver is a necessary adjunct to the development of the air/rock storage concept, since this storage system must operate at

slightly higher temperatures (1100$^{o}$F to 1200$^{o}$F). Several materials would be evaluated for this application and a test unit designed and fabricated. The receiver would be tested at flux levels up to 1.500MW/M$^2$, with sodium outlet temperatures not to exceed 1200$^{o}$F.

Air/Rock Storage, $1.0 mil. The economic viability of an all-liquid type central receiver concept as an energy option will be greatly enhanced by the development of the air/rock storage concept which shows the potential for economical quasi-baseload type of operation. The technical performance and operating characteristics of the air/rock system needs to be verified before the private sector can take over the engineering development and application. The operating and economic benefits associated with a long duration storage system with up to 12 hours of full power operating capacity would be analyzed. A system designed to operate with 1100$^{o}$F air would be tested to determine storage charge and discharge capability, durability of the rocks, temperature distributions, and pressure drop.

c) In order to reduce operating costs of both small and large scale plants, commercial development and testing of automated, unattended control systems is required. It is envisioned that this effort would culminate in test loops either at Solar One or CRTF. A $1.0 mil funding level is recommended for FY '85.

## 2. EXPERIMENTS

### a) Solar One Operations, Maintenance and Analysis

This item provides $4.6 mil for the continued operation of Solar One test and evaluation activities, and initiating the utility power production phase.

(1) An analysis of test data to compare predicted and actual plant parameters to verify design performance. Developing operating strategies to increase plant output and improved economics.

(2) Collector (heliostat) tests and evaluations to derive beam pointing, beam quality, and reflectivity data. Heliostat cleaning requirements will be established.

(3) Plant maintenance evaluations will be conducted, including the analysis of the reliability of equipment, the identification of preventive maintenance needs, and receiver repair activity.

(4) "Lessons learned" documentation for design, construction, operational phases and technology transfer.

### b) MSEE Operations & Test

Molten Salt Electric Experiment Operations & Test: $2.4 mil. The Molten Salt Electric Experiment, made operational in 1984, requires continued support in the advanced testing phase. Design and construction (Phase I) will be completed in 1984. Operational testing and training (Phase II) is planned for completion in GFY'84. A Phase III program--advanced testing--is recommended for GFY'85. This testing will be conducted by teams of user and designer/manufacturer personnel and will, upon completion, provide a greater degree of understanding of systems/hardware uncertainties to users. This program provides for both technology transfer and for development of a broader base of experimental experience from which future molten salt technology development requirements can be defined.

c) Large Scale Experiments

This item provides $10.3 mil in FY'85 for direct support of one or more industrial team projects. This will provide a relatively low level of government cost sharing for a portion of the R&D effort required and will allow industry to meet otherwise unachievable project financing hurdles and to proceed with projects currently on the board. Follow-on funding at a level of $15 mil/yr for FY'86 and FY'87 will complete this requirement and bring STCR technology into private sector acceptance.

d) Small, Remote System Concepts:

International applications of STCR technology in remote locations is being explored by many governments including Canada, France and Switzerland. The smaller/remote locations are potentially suitable for STCR technology since current electric generation costs are on the order of 16-20¢/KWh. An amount of $0.5 mil is recommended for cooperative, exploratory studies of smaller system and component applications for remote deployment.

## C. DISTRIBUTED COLLECTOR TECHNOLOGY DEVELOPMENT

### 1. PARABOLIC DISH

The parabolic dish technology development program of $11.9 mil shall continue research in the electric and thermal applications. Dish electric module development shall consist of $2.5 mil for the brayton module developments and $1.7 mil for the terrestrial solar application of the NASA sponsored 25 KW free piston Stirling engine. The shift of lead center responsibilities shall provide a shift to thermal applications of parabolic dishes and consequently fund $1.2 mil for such activities with $1.5 mil for operations of Distributed Receiver Test Facility. The Innovative Concentrator Program started in FY 84 shall continue at $3.0 mil. The Small Community Solar Experiments shall be supported with a total of $1.0 mil reserved strictly for operations and maintenance of these systems for a sufficient period of time to fully gain the data and experience associated with this project(s). In the same context, $0.5 mil shall be provided to continue data collection at selected representative parabolic trough facilities. As presented in the President's budget, $0.5 mil shall be provided for capital equipment.

### 2. PARABOLIC TROUGH - Components, Materials & Performance

A funding level of $0.5 mil is recommended for completion of the operating phase of existing IPH and MISR projects, to obtain data from trough systems which remain operational and to support refurbishment and/or retrofit of specific systems which represent commercial prototypes. Until first commercial projects are in operation, existing DOE funded systems are the only ones available for use as industrial marketing tools. For this reason, their efficient performance and continuing operation is mandatory.

## D. PLANNING AND PROGRAM SUPPORT

1. Approximately $1.7 mil is recommended by the industry for allocation in the area of planning and coordination of solar thermal activities. These activities should be directed toward all technologies, with emphasis on short term and long term planning, analysis, assessment of technical and economic issues, and program evaluation and documentation to ensure a balanced and effectively prioritized program. These activities are conducted by a core staff comprised of personnel from several DOE labs with support from other subcontracted organizations uncoupled from any one solar technology to obtain unbiased results. The industry opposes activities dealing with cost goals, since such activities tend to have a negative effect on private-sector marketing activities.

The planning and documentation effort resulting in preparation of Annual Operating Plans, Multiyear Program Plan, Annual Evaluation Report, etc., are important for the management and evaluation of the current program, as well as planning for future research and development.

This activity is expected to continue in out-years at approximately this level.

# STATEMENT OF
# FRANK F. DUQUETTE
CHAIRMAN
SOLAR THERMAL DIVISION
SOLAR ENERGY INDUSTRIES ASSOCIATION

BEFORE THE
SUBCOMMITTEE ON
ENERGY DEVELOPMENT AND APPLICATIONS
OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

MARCH 1, 1984

"No single prescription exists for a solution to the energy problem. Energy conservation is not enough. Petroleum is not enough. Coal is not enough. Nuclear energy is not enough. Solar energy and geothermal energy are not enough. New ideas and developments will not be enough by themselves. Only the proper combination of all of these will suffice."

-- Energy From Heaven and Earth, 1979

## 1.0 FOREWORD

This presentation describes solar thermal systems that can provide significant displacement of our fossil fuel resources by supporting industrial energy needs. The technology offers potential for not only providing an environmentally clean energy source, but also stimulating industrial growth with the associated jobs, tax revenue and other benefits.

The discussion outlines past accomplishments of the government/ industry partnership in developing this technology and the need for a moderate level of continuing government support to achieve timely transfer to the private sector for a multiplicity of applications.

Technology readiness and market acceptance, financial and technical barriers, potential oil displacement, other government financial support options and related benefits are outlined.

The industry recommended FY'85 DOE R&D budget for solar thermal technology is $54.7 million. We believe this funding level provides a balanced mix of longer term high-risk research with the effort required to complete development of near term high payoff system and subsystem applications. In relation to the Energy Department's FY '85 requested total budget of 12.815 billion dollars, $54.7 mil represents a rather moderate 0.4% share.

## 2.0 INTRODUCTION

Mr. Chairman, members of the Committee, the Solar Thermal Division of the Solar Energy Industries Association appreciates this opportunity to testify on the FY 1985 budget pertaining to the solar thermal technologies. Once again, significant accomplishments and positive outlooks for the future have marked this past year as a result of an ongoing government/industry partnership. As an industry association, we can now envision, with the recommended budget levels, market acceptance of the technology with development risks regarded as managable by the private sector in the near term.

With regard to a related issue, we appreciate and support the Chairman's leadership in proposing an extension beyond 1985 of the Federal Energy Tax Credits which represent an appropriate role for the government to take to help create this emerging high technology industry.

## 2.1 SOLAR THERMAL DIVISION

The Solar Thermal Division, a division of the Solar Energy Industries Association, is an industrial organization fulfilling a vital role in the commercialization of solar thermal systems. Division member companies have consistently been at the forefront in advancing solar thermal technology through commitment of their own resources in close cooperation with federally supported research and development programs in solar energy. Ranging in size from large, multinational, energy and aerospace corporations to small, innovative firms, our members are world leaders in solar thermal technology. This leadership is based on experience gained through the 1970's, beginning with the early efforts of the National Science Foundation Solar Program. Nearly 10 years of accelerated effort have led to the development of advanced system designs that have exceeded almost all performance expectations. The transition from early engineering and test prototypes to full-scale operating systems for industrial and utility users is nearing reality.

This industry group, although not in agreement with the current administration's policies on renewable energy development, has responded to the policy shifts in the government's energy research and development program by implementing an orderly transition from system level engineering to a more research and applied development program. It should be kept in mind, however, the importance at this stage in this technology's development of the need to preserve the vast federal and corporate investment represented by existing test facilities. It is also important to continue and complete the component development program and last-step engineering phases that will help propel industry over the last major research and development hurdle that remains.

I know of no other renewable energy program that has met with more technical success, given the magnitude of the technical complexity. The government/industry partnership is working, and the end of direct support is within sight. Three years of additional direct support of the major technologies at level funding, relative to FY 1985, would appear to be adequate to complete the transition.

I firmly believe that the balance of this testimony will establish that there are significant technical dividends that have resulted from this committee's support of solar thermal technologies. I also believe that the work accomplished to date and the prospects for the future justify our FY 1985 budget request.

## 2.2 TECHNOLOGY SUMMARY

The major thrust of the government/industry partnership in the solar thermal program is to establish a capability in the private sector to deliver technically proven, cost-effective thermal systems for converting sunlight to low-, medium-, and high-temperature heat. Capabilities in these temperatures permit a range of potential applications which is unusually large and diverse. The heat can be used directly in industrial processes, be converted to electricity, or be applied directly to endothermic chemical reactions to produce fuels.

The technical feasibility of concentrating solar thermal systems has been established by a combination of government and industry supported efforts during the past decade. The federal/industry investment alone has reached a level of over 500 million dollars. The resulting cost of solar thermal energy hardware has dropped significantly in the years since the inception of the program.

The commercial viability of solar thermal energy systems is tied to full scale system level product readiness and to its cost/value relationship with other energy supply options. Further reductons in systems cost will be necessary in order for solar thermal energy systems to compete strongly with fossil fuel based systems and other renewable energy options. Furthermore, operation of commercial scale systems must be conducted for complete technology transfer to the private sector and to gain user industry acceptance.

Cost goals for economic competitiveness and user acceptance have been established for electricity generation and heat production as shown below for the year 1990. Cost goals on the order of 25-50 percent lower than 1990 levels will be achievable by 2010.

| Application | 1990 Goal (1983 $) |
|---|---|
| Electricity | 6-12¢/kWh |
| Heat | 7-12$/MBtu |

The following design basic concepts are continuing development under this program. These design concepts are:

- Central Receiver Systems
- Parabolic Trough Systems
- Parabolic Dish Systems

Hemispherical bowl and solar pond technology is either in the private sector or has been phased out of the program.

The table on the following page shows the market areas that offer the greatest market potential for each design concept.

Parabolic dish prototype hardware R&D&D is currently being successfully conducted in the field. Recent experience with test facilities and operating system experiments has demonstrated levels of equipment reliability and durability for heliostat systems and parabolic troughs which are consistent with market demands for specific applications. With the availability of government support for large scale system and subsystem experiments, mass production of collector prototypes already developed will reduce near term system costs to acceptable levels and promote the production levels needed to achieve stated cost goals in the 1990-2000 period.

## 2.3 MARKET ASSESSMENT

### 2.3.1 CENTRAL RECEIVER

In view of the administration's policy of supporting only high-risk long term research, the solar industry feels the urgent need to review the current state of development and commercial readiness of this technology. In particular, we want to highlight the importance of the central receiver technology and the need for government support of

| MARKETS ADDRESSED BY STES | MARKET SECTORS | SPECIFIC APPLICATIONS | APPLICABLE COLLECTOR/ CONCENTRATOR TECHNOLOGY | APPLICABLE STES PROJECTS/ACTIVITIES |
|---|---|---|---|---|
| ELECTRIC POWER | Large Utilities | • Repowering Existing Fossil-Fueled Plants<br>• New Capacity Additions<br>• Base Load<br>• Base Load (Site Specific) | } Central Receivers<br>Solar Ponds | • Barstow 10MWe Pilot Plant<br>• Utility Repowering<br>– Carissa Plains<br>– Saguaro<br>• Solar 100<br>• Salton Sea |
| | Small Community Systems | • Remote, Island Powerplants<br>• Military, MX-RES<br>• Municipals, Rural Coops | } Parabolic Dishes<br>} Bowls | • Small Community (EE-1)<br>• Military Module (EE-2A) |
| INDUSTRIAL | Process Heat | • Large, 200-2000°+F<br>• Small, 200-2000°+F<br>• Small, 200-600°F<br>• Low Temp. < 200°F, (Site Specific) | Central Receivers<br>Parabolic Dishes<br>Parabolic Troughs<br>Solar Ponds | • Industrial Retrofit<br>• Industrial Applications Experiments (EE-3)<br>• SCSE |
| | Cogeneration/ Total Energy | • Small Industrial, 200-1000°F | Parabolic Dishes | • Shenandoah<br>• Rancho Mirage |
| | | • Large Industrial | Central Receivers | • DOE Industrial Retrofit Adv. Concepts |
| | | • Small Industrial, Commercial, 200-600°F | Parabolic Troughs | • Mid-Temperature Solar Systems Test Facility (MSSTF) |
| | Production of Fuels and Chemicals | • Hydrogen Fuel<br>TBD | Central Receivers<br>Parabolic Dishes | • Explorator and Supporting Research (Seri/Sandia) |

TABLE 1

large scale experiments to achieve transfer to the private sector of its many applications and potential to provide environmentally clean, affordable utility power in the late 1980's, 1990's and beyond.

The solar thermal central receiver program, a program with 10 years momentum,is nearing the point of being passed from government to the private sector. This technology has not yet reached the stage in its development where it can be continued and completed by private capital alone. However, it is capable of being economically competitive and can help to stabilize and lower the cost of electricity for the ratepayer in the next decade. Utilities and power companies consider this potentially an important source of power generation for future generating capacity, but cannot complete development without shared federal assistance.

The research and development and proof of concept experiments have proven STCR to be technologically sound and environmentally safe. The STCR technology is modular and can be installed in four to seven years, as opposed to the eight to 15 years required for fossil fuel and nuclear generating facilities. And, more importantly, the technology provides for national and regional energy security by displacing foreign oil supplies. For example, a 100 MWe central receiver solar electric plant (capital cost approximately $400 million) would displace approximately 800 thousand barrels of oil per year. Industry studies indicate a potential market for 50-80 solar electric plants of this type in the southwestern U.S. through the year 2010, so that a total displacement of more than 40 million barrels of oil per year is realistically achievable. Additional oil displacement could be achieved for solar industrial process heat applications, including steam for enhanced oil recovery.

# SOLAR CENTRAL RECEIVER COMMERCIAL MARKET

Capacity (GW)

| EPRI Regional Areas | Existing Capacity | Projected Growth In Markets<br>Solar Thermal Only | | | |
|---|---|---|---|---|---|
| | | 1984-91 | 1992-96 | 1997-2002 | Growth Totals |
| Total ERCOT (Texas)<br>Texas Utility Company | (31)<br>17 | 5.4 | 4.9 | 5.9 | 16.2 |
| | | 0 | 0.8 | 1.5 | 2.3 |
| Total<br>WSCC (W-Tx, W-NM, Co, Wo, W-Mt, Id, Ut, Az, Ne, Ca, Or, Wa) | (43+) | | | | |
| CA (SDG&E, PG&E, SCE) | 35 | 4.6 | 4.0 | 6.0 | 14.6 |
| | | 0.2 | 1.4 | 3.0 | 4.6 |
| Others (APS, EPE, PNM, SRP, SPP) | 8 | 1.5 | 1.0 | 1.4 | 3.9 |
| | | 0 | 0.4 | 0.7 | 1.1 |
| Totals | 60 | 11.5 | 9.9 | 13.3 | 34.7 |
| | | 0.2 | 2.6 | 5.2 | 8.0 |

- Sizeable Market Exists — 8.0 GW = 80 100 MW Plants
- There is a time to be ready to close out competition

TABLE 2

### 2.3.2 UTILITY GENERATION

Generating capacity for the 1990 time frame and beyond is presently a part of utility planning activities. Several utilities are planning for central receiver power plants in their power generation forecasts for the following reasons:

> Solar can be used for short-term intermediate capacity operation previously served by oil and gas, such as the repowering of existing oil and gas fired units (post 1986 operations) and standalone plants.
>
> Smaller capacity additions on the order of 50-100 megawatts electric (MWe) are particularly suited to utility needs and avoid the problems of long licensing and permitting requirements and construction times associated with other types of projects, as well as significant reductions in capital funding requirements and the cost of that money.
>
> Integration and operation of central receiver power plants fit well into utility generation systems. The central receiver technology adapts reasonably well with available thermal electric generating technology, with which utilities are familiar and have extensive operating experience.
>
> These units, once the cost of construction is in place, offer protection against escalating fuel and transportation costs--issues of great importance to stabilizing utility rates for the customers of electric utilities.
>
> STCR operation is virtually free of air and water pollution and solid waste disposal problems and costs.

# 3.0 SIGNIFICANT ACCOMPLISHMENTS

## 3.1 CENTRAL RECEIVER

Significant progress continues for the development of solar central receivers technology and applications:

1) Solar One--the 10 MWe pilot plant for generating valuable performance and operating data since turbine roll in April 1982.

2) The ARCO Solar 1MW EOR System is consistently providing solar generated steam for heavy oil recovery near Taft, California.

3) An industry team was selected and is performing detailed design for a 30 MW grid repowering project with government cost sharing.

4) Southern California Edison has joined with industry to further develop project structure for Solar 100, the first commercial sized central receiver power plant at 100 MWe.

### 3.1.1 Solar One

The 10 MW solar thermal central receiver pilot plant became operational in April 1982 and is currently the world's largest electric generating station powered by solar energy.

This plant was the result of a joint effort between Southern California Edison, the Los Angeles Department of Water and Power, the California Energy Commission, and the U.S. Department of Energy. The plant has operated at 10.4 MW net electrical output, which is slightly in excess of its rated output, and has produced over 6,833,400 kWh of net energy through mid February 1984. Power output of 7.3 MWe from storage has been achieved, an accomplishment which satisfies another design milestone for the plant. Heliostat availability has been demonstrated to a 99% level with nominal maintenance. Fatigue cracks were detected in the high temperature solar boiler tubes during the latter part of 1983. Receiver structural modifications to substantially reduce thermal stresses and increase tubing lifetime were completed in February 1984. Studies are continuing to define means to further prolong receiver lifetime by revising heliostat aiming strategies to reduce receiver peak temperatures and thermal gradients.

The dual media thermal storage system has demonstrated that stable thermoclines can be maintained in an operational environment and plant automation continues on schedule for demonstrating a clear day operating scenario.

Valuable design verification data is being obtained from the naarly completed two-year test and evaluation program. The power production phase to allow hands-on utility operation will be initiated later this year and continue for one to three years.

### 3.1.2 Repowering

Four preliminary design studies for solar central receiver power plants have been completed. These preliminary design contracts involved significant cost sharing between the industry participants and the DOE. Three of these plants are for utility power generation operations with sizes from 30 to 66 MWe. They studied the use of liquid sodium, molten salt, and water as the heat transport fluids. The fourth design was a 31.8 MWe cogeneration project in Hawaii using water for heat transport.

DOE selection of a cost-shared detailed design effort was made utilizing the PG&E/Rockwell 30 MW sodium cooled receiver grid repowering design. This selection was based on an accelerated schedule in order to attempt to be on line in mid 1986.

The Arizona Public Service 66 MWe molten salt system design for repowering the Saguro plant has proposed an R&D approach for continuing development of the project.

It should be noted that the above projects, including the Solar 100 initiative, are struggling to maintain favorable economics in the face of current lower fossil fuel prices and the potential loss of energy investment tax credits after 1985.

### 3.1.3 Solar 100

Southern California Edison has been a leading utility in expressing interest in renewable energy sources, with plans for 2190 MW by the early 1990's. Of this, 300 MW electric has been designated to come from solar energy. SCE has given considerable incentive to industry through its Solar 100 solicitation.

Four companies responded to the Edison request to participate in a conceptual engineering study for a 100 MWe commercial plant. Late last year, Edison selected the McDonnell Douglas design approach utilizing a two module molten salt system. This user/designer team is currently developing a project structure which is targeted to be operational in the 1988-1989 time period.

## 3.2 PARABOLIC DISH

3.2.1 The Parabolic Dish Stirling Cooperative Agreement completed its design and fabrication phases. It is presently operating daily at Rancho Mirage, California and has achieved electrical outputs of 22.8 KW for a conversion efficiency of sunlight to electricity of 28.9%.

3.2.2 The Organic Rankine engine successfully completed 100 hours of simulated on-sun operations in the laboratory. The sub atmospheric brayton module achieved system checkout and integration, and the instrumentation and controls were developed.

3.2.3 U.S./Sweden industrial firms have consummated a cooperative agreement for the development and world marketing of commercial scale dish stirling concentrators (25KWe).

## 3.3 PARABOLIC TROUGH

3.3.1 An American Solar King 60,000 $ft^2$ commercial IPH line focus system is in operation for Gould Corporation.

3.3.2 Heavy effort to develop private sector financing for commercial projects is continuing.

3.3.3 MISR systems in operation at Sandia-Albuquerque and SERI are providing valuable test data and operating experience.

3.3.4 Operating data from 12 IPH projects is being made available to industry.

## 4.0 STATE OF THE INDUSTRY

Growth in electricity demand has outpaced U.S. GNP growth over the past twenty years, and this trend is expected to continue in the decade ahead. A recent study of the U.S. electric industry by the DOE Office of Policy and Planning and Analysis predicts that electricity usage will account for an increasing share of total U.S. energy usage. Furthermore, because of restraints on utility investments by regulatory agencies and the problems experienced by the nuclear industry, electric generating plant additions planned and under construction may be inadequate to meet the projected need by 1990. Considering the lead times required for major plant construction, an even more serious shortfall (as much as 60GW) could result if the economy expanded at a 1% higher than projected annual rate, and if some of the plants now in construction are not completed or are cancelled.

With a moderate amount of continuing Government support, solar thermal electric systems can provide a contribution to meeting the need for generating capacity during the latter half of the decade due to their shorter construction lead times, and can provide an attractive option to other generating alternatives, such as combustion turbines.

A just released Frost and Sullivan market study estimates that solar thermal electric systems will contribute 10GW to the world power grid by 2010. Solar related equipment and service sales are also seen rising from the 1982 level of $488 million to $6 billion by 2010. To put this growth forecast in perspective, market penetration for this environmentally clean, renewable energy option moves from 20 MWe in 1982 to 10,000 MWe by the first decade of the next century.

It should be noted, however, that with reduced federal support for solar, along with a strong dollar that drives up the cost of U.S.-made goods abroad, the study sees Japan moving into the market.

"Very large individual plants are planned in both the USSR and India," and the study predicts that "as Japan and the Far East begin to recognize the importance of solar electric generation, we will see dramatic changes" in their level of investment.

A recent market penetration study conducted by one of our industrial member firms forecasts a potential of as many as 80 100 MWe solar central receiver plants fulfilling utility power intermediate load needs in the southwestern U.S. by 2002. Refer to table in Figure 1.

## 4.1 BARRIERS TO COMMERCIALIZATION

A number of issues must be resolved to clear the hurdle for commercial scale hardware project experiments leading to market acceptance:

Financing: Project financing is not available for large new technology plants. Further, the high initial cost compared to revenues available at current electrical energy price precludes returns on investment required in the marketplace. Private sector investors are concerned about the availability of the 15% investment tax credit extension to 1992, and possible enhancement.

Risks: Neither industry, utilities nor ratepayers are able to assume a disproportionate amount of the financial risk for first large scale experiments. Government support in the form of loan guarantee or energy price guarantee and technology budget outlay is required.

Regulation: Federal law exempts third parties from utility regulation for solar plants less than 30 MW. Larger plants are subject to utility regulation unless exemptions can be obtained for accounting, tax implications, and other burdens of utility regulation which are difficult for third party investors.

Technical: Some residual component and subsystem technology verification remains to be accomplished by the government's research and development program.

Energy Cost: Electrical energy prices today are depressed by current low oil and natural gas prices. This creates an imbalance between plant value and cost at this time.

## 4.2 SUMMARY OF SEIA/INDUSTRY STUDIES AND REPORTS

During 1983, the SEIA completed several studies on the current status of the solar thermal industry. They are:

An Assessment of the Impact on the Solar Central Receiver Industry if Federal Energy Investment Tax Credits Are Not Extended in 1983

The Availability of Industrial Capacity to Produce Solar Thermal Energy Systems

Avoided Cost Standards and Practices Under the Public Utility Regulatory Policies Act

### Assessment of Failure to Pass a Tax Credit Extension

Review of the status of central receiver technology revealed the initial dependence of commercialization this technology has on extensions of the business energy investment credit. In 1983, four preliminary designs for repowering plants were completed, and a team selected to proceed with a final design of a 30 MW plant. Two other initiatives continue to be active, a 100 MW plant proposed to Southern California Edison Company, and a 60 MW plant proposed by the Arizona Public Service Company.

Readying this technology for commercial introduction requires successful operation of a plant larger than the Solar One experiment. Change in the basic strategy of the federal R&D program has placed reliance on the private sector for funding construction and operation of such a plant. To date, no third-party group has been assembled to maintain a CR project. With expiration of the credits now 22 months hence, construction lead times of three to four years, and the need to place key component orders in mid-1984 for any plant to begin construction in the next 12 months, it is completely unlikely any project will go forward without extension of the tax credits before summer 1984. Should Congress fail to extend the credits, the SEIA assessment indicated the following could occur:

> Failure to pass the credits extension legislation in 1983 signals a major defeat for the several projects still trying to arrange finance and get construction started.
>
> The investment community loses interest in central receiver projects because planning cannot be initiated or sustained with the high degree of uncertainty about financing.
>
> The solar companies retrench, halt their own market development expenditure, but continue to bid R&D contracts as they become available. The companies begin to pay more attention to longer-range applications, such as fuels and chemicals. Some may consider trying to develop small industrial process heat systems.
>
> Near-term commercialization ceases because the interested utility companies abandon central receiver technology. They see industry halting commercialization activity, and because their planning horizon has already stretched out to 1995, they give it up.

> The abandonment of near-term commercialization by industry reduces industry pressure on Congress and the Department of Energy to maintain the present levels of appropriations for solar thermal R&D. Nonetheless, industry may beseige Congress with a plan for a fully government-supported commercial demonstration plant, contending higher petroleum prices will so raise avoided costs in the 1990's that utilities will renew their interest in central receiver technology.
>
> Base technology support for Solar One, the Molten Salt Electric Experiment and Repowering is eliminated from the R&D program, and the federal budget is reduced accordingly.

This assessment was prepared with the cooperation of several companies involved in central receiver technology. It does not represent a formal Solar Thermal Energy Division statement.

## Industrial Capacity to Produce Solar Thermal Energy Systems

SEIA reviewed forecasts of power plant construction through the 1980's and the historical accuracy of such forecasts from 1978 to 1982. Capacity utilization of equipment manufacturers for fossil and nuclear power plants and of aerospace companies was analyzed. Because they account for approximately forty percent of central receiver plant capital cost, industry approaches to mass producing heliostats were also examined.

This survey of conditions in the power market and industry capable of delivering central receiver technology revealed two important findings. First, projections of utility plant capacity additions have usually overstated actual construction, and, if trends in the recent past continue, very little new business for the power equipment industry will be forthcoming this decade. Consequently, the power generation equipment industry is suffering a severe under-utilization of its capacity. It is capable, with a minimum of new investment, of meeting any expected demand in the 1980's for solar central receiver plants. If conventional plant manufacturers decommission capacity, but a market develops in five tc seven years based on replacement of aging power plants, solar thermal plant constructors may find they have to compete for capacity to produce their systems.

The second finding concerns production of heliostats. A survey of potential suppliers of heliostats revealed two paths to creation of mass production capability. Aerospace firms involved, despite their own excess capacity, expect to invest in new facilities for large volume production. Another major participant has identified a second approach, however, which would minimize investment in production facilities and rely on existing capacity that is producing on a regular basis most of the parts needed to build a heliostat. It is unclear which of these paths will be the foundation of the commercial introduction of central receiver technology.

## Avoided Cost Standard and Practices Under the Public Utility Regulatory Policies Act

The Solar Energy Industries Association examined the relevance of PURPA legislation, specifically Sections 210 and 201, to solar thermal project developers. The study provides an understanding of the avoided cost standard used by electric utilities to calculate the price paid to small power producers, and of the interconnection and qualifying requirements for such producers. SEIA also surveyed important actions state utility commissions and utilities have taken and the limited experience to date of solar thermal projects proposed under PURPA guidelines.

The court challenges to Federal Energy Regulatory Commission rules implementing PURPA provisions favoring independent power producers have been decided in FERC's favor. Most states have proceeded to adopt the FERC rule and established rates which meet the definition of full avoided costs. Compliance with PURPA has therefore been almost universal; but, in practice, the result has been a great variety of rate-setting methods. Thus, after four years, avoided cost is still an evolving issue.

Opportunities exist to improve the avoided cost picture for solar thermal projects, and would concentrate on:

Identification of the most favorable marginal plants

Avoiding use of historical averages

Inclusion of O&M and line loss factors in avoided cost calculations

Another area of dispute concerns capacity credits, which can amount to as much as 10 percent of full avoided costs. Capacity credits have so far proven difficult to calculate and are controversial. One problem is in predicting accurately the future generation mix of a utility's baseload facilities and its true avoided capacity costs. Few widely accepted methods exist, and room for interpretation is great.

Support for capacity credits for solar thermal systems should be readily forthcoming given performance to date of the 10 megawatt pilot plant (Solar One) at Barstow, California.

Examination of issues surrounding establishment of power purchase rates for independent power producers revealed that alternative approaches may be required. A fundamental question unresolved is who would help pay for development of new power generation technologies.

## 5.0 PROPOSED FY 1985 BUDGET

The Administration's FY 1985 budget request for the Solar Thermal Technologies discussed today is only $37.5 million. This figure represents only something over one-half of our industry request.

The STEA considers the Administration request inadequate in light of the significant accomplishments and the remaining tasks. Included herein is a comprehensive alternative budget that totals $54.7 million. In the next section, we have spelled out our rationale for each line item and we feel that our submission represents a realistic and balanced approach to the development of solar thermal energy. The difference in the two budget requests represents the difference between having a viable, near term, job-producing industry, or a program resulting in longer delays and the potential of loss of significant industry involvement and support.

FINAL
2/24/84

## SEIA SOLAR THERMAL DIVISION
## FY 85 TECHNOLOGY BUDGET RECOMMENDATIONS

| | | | | |
|---|---|---|---|---|
| A. RESEARCH | | | | 13.9 |
| 1. EXPLORATORY | | | | |
| a) Materials | | 3.3 | | |
| b) Innovative Concepts (PRDA - New & Follow-on) | | 1.0 | | |
| c) University Thermal Research | | 1.7 | | |
| d) Photo/Thermal Chemical | | .7 | | |
| 2. SUPPORTING | | | | |
| a) Innovative Collectors, Concentrators and Refractive Devices | | 2.0 | | |
| b) Parabolic Trough Materials | | 0.5 | | |
| c) Parabolic Dish Materials, Controls & Thermal Storage | | 1.8 | | |
| d) Fuels & Chemicals (Hi-Temp Receiver/Reactor 1500°F-2500°F) | | 2.9 | | |
| B. CENTRAL RECEIVER RESEARCH & DEVELOPMENT | | | | 26.7 |
| 1. SUBSYSTEM/COMPONENT DEVELOPMENT | | | 8.9 | |
| a) CRTF Operations | | 1.4 | | |
| b) Subsystem Component Development<br>-2nd Generation Receiver<br>-Steam Generator, Storage | | 6.5 | | |
| c) Automated, Unattended Control System | | 1.0 | | |
| 2. EXPERIMENTS | | | 17.8 | |
| a) Solar I | | | | |
| -O&M | | 3.6 | | |
| -Performance Analysis & Test | | 1.0 | | |
| b) MSEE Operations & Test | | 2.4 | | |
| c) Large Scale Experiments<br>-Direct support of one or more industrial team projects | | 10.3 | | |
| d) Small, Remote System Concepts | | 0.5 | | |
| C. DISTRIBUTED COLLECTOR TECHNOLOGY DEVELOPMENT | | | | 12.4 |
| 1. PARABOLIC DISH | | | 11.9 | |
| a) Test Facilities | | 1.5 | | |
| b) Thermal Transport | | 1.7 | | |
| c) Dish Electric | | 4.2 | | |
| -Brayton | 2.5 | | | |
| -Free Piston Stirling | 1.7 | | | |
| d) Adv. Concentrator | | 3.0 | | |
| e) Small Community System Experiment | | 1.0 | | |
| f) Capital Equipment | | 0.5 | | |
| 2. PARABOLIC TROUGH - Operation, Refurbishment & Performance Data | | | 0.5 | |
| D. PLANNING AND PROGRAM SUPPORT | | | | 1.7 |
| TOTAL | | | | 54.7 |

## 5.0 PROPOSED FY 85 BUDGET

## SEIA SOLAR THERMAL DIVISION
## FY 85 TECHNOLOGY BUDGET RECOMMENDATIONS

### A. RESEARCH

#### 1. EXPLORATORY

a) Materials. An amount of \$3.3 mil is recommended for work in the following areas: Reflective surfaces (glass, plastic, acrylic coatings, etc.); anti-reflective, selective and absorptive coatings; seals; improved glass (thin, strength); high temperature, flexible hoses; structural materials (weight, price, strength, cycle life); ceramics; transparent windows; cavity insulation and shielding at operating temperatures; insulation for high-flux systems (1.5 $MW/m^2$ to 2.0 $MW/m^2$); corrosion-resistant properties of low-cost materials for nitrate salts; and measurements of physical properties of nitrate salts.

b) Innovative Concepts (PRDA - New and Follow-on)

An amount of \$0.5 mil is recommended for solicited innovative research. It is recommended that evaluation of the PRDA responses be carried out or monitored by a peer review committee incorporating a majority of university researchers. This will both assure the high quality of the research undertaken and assure that the research is outside the area of immediate problem solving. It is also recommended that \$0.5 mil be made available for two to three follow-on experiments (Phase II) selected from the present innovative research contracts.

### c) University Thermal Research

The expansion of the solar thermal technology base for cost effective approaches to future commercial market applications requires continuity of research direction and funding. In the view of industry, the research program should be addressing the needs related to performance improvement, cost reduction of critical subsystems (collectors, receivers, etc.) and expansion into new applications such as fuels and chemicals. The research should emphasize the removal of technical barriers prior to engineering development by industry.

Research work carried out by U.S. universities continues to be useful in identifying promising concepts and processes in solar thermal technology and transitioning technology to private industry. It is recommended to continue funding for the ongoing Solar Thermal Advanced Research Activity Center (STARC) at the University of Houston (UH) at $0.7 mil and at GIT at $1.0 mil. The GIT funding level recognizes the presence of the Advanced Components Test Facility (ACTF) at GIT and includes $0.25 mil to maintain it in an operational status.

### d) Photo/Thermal Chemical

$0.7 mil is recommended for basic research of photochemical effects of high flux and high temperatures for various atmospheres. This work is needed to better understand degradation of receiver surface materials, both for external and direct flux particle receivers.

2. SUPPORTING

a) Innovative Collectors, Concentrators and Refractive Devices

Reflector materials development for low cost, lightweight concentrators. The program includes research and small scale experiments to develop silvered polymeric reflectors having 92% reflectance, 15 year life, and resistance to ultraviolet and environmental attack. The program will also include research to establish the feasibility of polymer materials for structural membranes with an emphasis on creep fatigue, durability under wind and hail impact, ease of handling and attachment, optical quality, stability and weatherability ($1,950,000).

b) Parabolic Trough Materials

A funding level of $0.5 mil is provided to support continuing generic R&D for components and materials which will provide higher performance, lower capital costs and longer lifetime for trough hardware. A priority need is for lower cost, 20-year life, relfective services with greater than 96% reflectivity, and high production volume cost of $\$1.50/ft^2$ or better. Other important areas include high temperature heat transfer fluids; higher emmissivity, long life, absorptive coatings for receivers; long life, stable evacuated tube receivers.

c) Parabolic Dish Materials, Controls and Thermal Storage

The materials and component research program shall support the parabolic dish technology by providing $1.8 mil towards heat pipe/thermal storage receivers, application of fiber optics for dish controls and reflective surface material development for compound curvature applications.

d) Fuels and Chemicals

Thermo chemical and high temperature receiver/reactor ($1500^{\circ}F$-$2500^{\circ}F$) concepts definition and development. Although the solar thermal industry recommends that R&D in the area of the application of solar thermal processes to the production of fuels and chemicals be continued, we do not feel that it should have a high priority since it cannot have a near-term impact on stabilization of energy prices or on energy independence. We do feel, however, that a $2.9 mil effort is justified, provided it is expended on research of processes and systems that can potentially apply to a broad range of current industrial processes and with increased chemical industry participation. Direct flux particle receivers need basic/exploratory research as well as development. Even though, for example, a long-term goal of producing hydrogen by means of thermochemical processes appears to be promising, that goal should be reached via analyses, research, and development which can be of use to the U.S. industry in the near term. The industry feels that funding for research and development in the field of fuels and chemicals should be kept at a relatively low level until the nearer-term technology development applying to the parabolic dish and central receivers is at a stage at which it can and will be picked up by the private sector for commercialization. Out-year budgets for fuels and chemicals are, therefore, recommended for increases consistent with the potential impact they can have on the longer term energy supply for the U.S.

## B. CENTRAL RECEIVER RESEARCH & DEVELOPMENT

### 1. SUBSYSTEM/COMPONENT DEVELOPMENT

### a) CRTF Operations

The CRTF continues to be a valuable research tool for central receiver development. The ability to transfer the solar central receiver technology to the private sector at any time will depend to some extent on the degree to which the technical feasibility of the process or the performance of a component has been verified at a real solar source. In addition, private industry anticipates a need to have facilities available (much like those available for high energy physics or nuclear research) at which testing can be conducted on hardware designed and fabricated by private industry. Any given private organization could not afford or justify keeping a facility active on the basis of the infrequent times at which its own needs must be met. Industry feels, therefore, that this need should be logically and properly met by federal involvement. A budget of $1.4 mil is recommended for FY 1985, and similar budgets are required for out-years for this facility.

### b) Subsystem/Component Development

One of the major barriers that impedes the ability of industry to pick up the central receiver technology is the high cost and high risk associated with the development of certain key central receiver components. Principally, these components are the receiver, the steam generator, and storage. In order to reduce the perceived risk of these components to the point at which the private sector can pick them up and complete the development for commercialization, the industry recommends a base technology development effort which includes the receiver as well as the other two key components, for both molten salt and sodium systems.

Recommendations for molten salt work are as follows:

> Extended Receiver Test, CRTF: $0.5 mil. Twelve month extended lifetime and performance testing of Category B 5 $MW_t$ model molten salt receiver.
>
> Continued development of operating strategies including overnight drain-down vs warm stand-by, transient responses, and reduction of thermal cycling effects. Extended testing and experience with heat tracing and salt line instrumentation.
>
> Extended Pump and Valve Test, CRTF: $0.8 mil. Twelve month extended full-scale molten salt pump and valve testing for performance and reliability. Data to be collected under both hot (1050°F) and cold (530°F) conditions. If only the hot (or cold) loop tests are conducted under Category B, then the corresponding cold (or hot) loop tests must be conducted here. Extended testing and experience with heat tracing and salt line instrumentation.
>
> Storage Tank Thermal Cycling: $1.1 mil. New experiments with molten salt storage tanks to test a scale version of the preferred full-scale design for resistance to thermal cycling and for leak detection methods.

Physical Property Test, Cover Gas and Metals Corrosion: $0.3 mil. Extended monitoring of molten salt properties, including the addition of additives for lowering the melting point and raising the operating temperatures, the evaluation of several cover gases in storage tanks and continued and expanded operation of the molten salt corrosion test loops at CRTF. Dismantling and inspection of MSEE molten salt steam generator for abnormal corrosion effects.

Liquid Sodium Recommendations Follow:

> Reheater, $1.0 mil. While sodium-to-water steam generators have been developed for the evaporator and superheater mode of operation, operation in the reheater mode is sufficiently different so that development and testing is required. There are no U.S. manufacturers of steam generators which operate in this mode. The use of reheat will allow a significant improvement in turbine efficiency for solar systems and will allow them to be more competitive with fossil-fired plants. This development activity would include the design and analysis of plant sized reheater units for operation at 1100°F sodium temperature followed by the fabrication and test of a prototype test unit.
>
> 2nd Generation Receiver, $1.0 mil. A second generation receiver is a necessary adjunct to the development of the air/rock storage concept, since this storage system must operate at

slightly higher temperatures (1100°F to 1200°F). Several materials would be evaluated for this application and a test unit designed and fabricated. The receiver would be tested at flux levels up to 1.500W/M$^2$, with sodium outlet temperatures not to exceed 1200°F.

Air/Rock Storage, $1.0 mil. The economic viability of an all-liquid type central receiver concept as an energy option will be greatly enhanced by the development of the air/rock storage concept which shows the potential for economical quasi-baseload type of operation. The technical performance and operating characteristics of the air/rock system needs to be verified before the private sector can take over the engineering development and application. The operating and economic benefits associated with a long duration storage system with up to 12 hours of full power operating capacity would be analyzed. A system designed to operate with 1100°F air would be tested to determine storage charge and discharge capability, durability of the rocks, temperature distributions, and pressure drop.

c) In order to reduce operating costs of both small and large scale plants, commercial development and testing of automated, unattended control systems is required. It is envisioned that this effort would culminate in test loops either at Solar One or CRTF. A $1.0 mil funding level is recommended for FY '85.

2. EXPERIMENTS

a) Solar One Operations, Maintenance and Analysis

This item provides $4.6 mil for the continued operation of Solar One test and evaluation activities, and initiating the utility power production phase.

(1) An analysis of test data to compare predicted and actual plant parameters to verify design performance. Developing operating strategies to increase plant output and improved economics.

(2) Collector (heliostat) tests and evaluations to derive beam pointing, beam quality, and reflectivity data. Heliostat cleaning requirements will be established.

(3) Plant maintenance evaluations will be conducted, including the analysis of the reliability of equipment, the identification of preventive maintenance needs, and receiver repair activity.

(4) "Lessons learned" documentation for design, construction, operational phases and technology transfer.

b) MSEE Operations & Test

Molten Salt Electric Experiment Operations & Test: $2.4 mil. The Molten Salt Electric Experiment, made operational in 1984, requires continued support in the advanced testing phase. Design and construction (Phase I) will be completed in 1984. Operational testing and training (Phase II) is planned for completion in GFY'84. A Phase III program--advanced testing--is recommended for GFY'85. This testing will be conducted by teams of user and designer/manufacturer personnel and will, upon completion, provide a greater degree of understanding of systems/hardware uncertainties to users. This program provides for both technology transfer and for development of a broader base of experimental experience from which future molten salt technology development requirements can be defined.

c) Large Scale Experiments

This item provides $10.3 mil in FY'85 for direct support of one or more industrial team projects. This will provide a relatively low level of government cost sharing for a portion of the R&D effort required and will allow industry to meet otherwise unachievable project financing hurdles and to proceed with projects currently on the board. Follow-on funding at a level of $15 mil/yr for FY'86 and FY'87 will complete this requirement and bring STCR technology into private sector acceptance.

d) Small, Remote System Concepts:

International applications of STCR technology in remote locations is being explored by many governments including Canada, France and Switzerland. The smaller/remote locations are potentially suitable for STCR technology since current electric generation costs are on the order of 16-20¢/KWh. An amount of $0.5 mil is recommended for cooperative, exploratory studies of smaller system and component applications for remote deployment.

## C. DISTRIBUTED COLLECTOR TECHNOLOGY DEVELOPMENT

### 1. PARABOLIC DISH

The parabolic dish technology development program of $11.9 mil shall continue research in the electric and thermal applications. Dish electric module development shall consist of $2.5 mil for the brayton module developments and $1.7 mil for the terrestrial solar application of the NASA sponsored 25 KW free piston Stirling engine. The shift of lead center responsibilities shall provide a shift to thermal applications of parabolic dishes and consequently fund $1.2 mil for such activities with $1.5 mil for operations of Distributed Receiver Test Facility. The Innovative Concentrator Program started in FY 84 shall continue at $3.0 mil. The Small Community Solar Experiments shall be supported with a total of $1.0 mil reserved strictly for operations and maintenance of these systems for a sufficient period of time to fully gain the data and experience associated with this project(s). In the same context, $0.5 mil shall be provided to continue data collection at selected representative parabolic trough facilities. As presented in the President's budget, $0.5 mil shall be provided for capital equipment.

### 2. PARABOLIC TROUGH - Components, Materials & Performance

A funding level of $0.5 mil is recommended for completion of the operating phase of existing IPH and MISR projects, to obtain data from trough systems which remain operational and to support refurbishment and/or retrofit of specific systems which represent commercial prototypes. Until first commercial projects are in operation, existing DOE funded systems are the only ones available for use as industrial marketing tools. For this reason, their efficient performance and continuing operation is mandatory.

## D. PLANNING AND PROGRAM SUPPORT

1. Approximately $1.7 mil is recommended by the industry for allocation in the area of planning and coordination of solar thermal activities. These activities should be directed toward all technologies, with emphasis on short term and long term planning, analysis, assessment of technical and economic issues, and program evaluation and documentation to ensure a balanced and effectively prioritized program. These activities are conducted by a core staff comprised of personnel from several DOE labs with support from other subcontracted organizations uncoupled from any one solar technology to obtain unbiased results. The industry opposes activities dealing with cost goals, since such activities tend to have a negative effect on private-sector marketing activities.

The planning and documentation effort resulting in preparation of Annual Operating Plans, Multiyear Program Plan, Annual Evaluation Report, etc., are important for the management and evaluation of the current program, as well as planning for future research and development.

This activity is expected to continue in out-years at approximately this level.

Mr. **Bateman**. Thank you very much, Mr. Duquette.

If members have questions, we might raise them at this time. I am going to withhold all mine, in deference to hearing the rest of the panelists before presenting mine. But other members who may have to leave, do you have questions now?

Mrs. **Schneider**. Unfortunately, I do have to leave, so just let me ask one question. How helpful do you feel that the Solar I project really has been in moving us more quickly toward the commercializing of solar thermal technology, in terms of time lines and in terms of cost?

Mr. **Duquette**. I think that the Solar I project has really been the baseline of validating actual system and hardware operation that tells the rest of the industry, the users and the suppliers and the rest of the world that the technology can work; it is proven. It has been extremely useful from that point of view. In fact, it really has been the flagship, not only of this Nation's effort in central receiver technology but in the world.

Mrs. **Schneider**. Insofar as technology transfer, which seems to be a real difficulty that keeps coming up again and again on this committee, how do other people across the country or in the international market become of the Solar I project? That mechanism exists for that technology transfer?

Mr. **Duquette**. There is a mechanism that is supported by the Department of Energy and supported by the industry in which there are regular reporting sequences of the performance, of the problems, of the lessons learned, and the items of interest that will benefit the rest of the industry, either nationally or internationally. I think that the Department of Energy has done an excellent job in attempting to transfer the technology up to this point.

Mrs. **Schneider**. I see a few others shaking their heads, so I guess there is some agreement there.

What have been some of the major problems in scaling up from a 10 megawatt to a 100 megawatt?

Mr. **Duquette**. Actually, the 10-megawatt plan is the water steam system, and it has been operating very successfully. We have had some fatigue cracks and boiler tubes and things, but that is what a pilot plant is all about. We are learning a lot about it and taking steps to work around some of those design situations. In the larger, commercial-size next-step plants, we are talking about the utilization of either molten salt with a heat transfer medium or liquid sodium. We have done some subscale testing at the central receiver test facility in Albuquerque in both of these areas. I guess the major problem is to carry what we have done into larger-scale subsystem prototype and system development experiments. That is really the thrust of what we have talked about here today.

Mrs. **Schneider**. Thank you, Mr. Chairman. I regret that I am going to have to leave in a little while for another hearing, but I found the testimony very enlightening and will check into the written testimony of the other members of the panel.

Mr. **Duquette**. Thank you very much.

Mr. Chairman, I did want to have a short amount of time for my associates on each side just to at least gently touch on the larger project.

Mr. **Bateman**. We would be certainly desirous of hearing from them. If it is agreeable to everyone else, we would be happy to hear Mr. Springer's comments at this time.

## STATEMENT OF THOMAS H. SPRINGER, PROGRAM DEVELOPMENT MANAGER, SOLAR ENERGY SYSTEMS, THE ENERGY SYSTEMS GROUP, ROCKWELL INTERNATIONAL, CANOGA PARK, CA

Mr. **Springer**. Thank you, Mr. Chairman. I am the program manager of solar systems at the Energy Systems Group of Rockwell International, and I am vice president of the Solar Energy Industries Association that Frank referred to, and a member of the Solar Thermal Division. It is from that position that I am going to make some remarks with regard to the Solar Thermal Division's budget that Frank just outlined and, in particular, some items in that budget and how they relate to a very specific project that we are participating in.

In addition to those budgetary connections, I would also like to comment upon the energy tax credit, even though it is not within the purview of this committee, and how those tax credits have an impact on this particular project, not only in the fact that they do exist but that this project is very closely related to when some action can be taken on that.

The specific solar thermal project to which I am referring is a 30-megawatt electric solar central receiver concept called the Carrisa Plains. It is similar to the Barstow plant and, in our opinion, can serve as the next evolutionary step in progressing from the largely Government-financed Solar I to a large-scale totally private-sector-financed commercial plant for the future. So we look at it as transitional precommercial item.

We are in the final design stage on this particular project, and the participants, in addition to Rockwell International, are Arco Solar Industries, Bechtel National, and the Pacific Gas and Electric, as Frank Duquette mentioned. The plant is of a size that would supply enough electrical energy for about 12,000 homes and save approximately 160,000 barrels of oil annually. We put enough storage in this particular plant to operate for about 70 minutes without any solar input.

Whereas, as Frank mentioned, Solar I employs water as the heat transport fluid, the Carrisa Plains plant is being designed to utilize liquid sodium. Sodium has an extremely high heat transport property that will allow selected components, such as the receiver on top of the tower and steam generators and components like that, to be rather small in size. The technology for sodium is very well established. There has been at least 30 years of Government-sponsored and privately-sponsored research that has gone into it. Except for the receiver on top of the tower, all of the heat transfer components are basically ready. They have been tested in sizes much larger than we would anticipate for this particular plant and even for plants in the future that would be commercial size. The components also have been operated at temperatures well in excess of what we anticipate for the Carrisa Plains plant in particular.

Although that is true about the components, a complete solar-type system, using liquid sodium as the heat transport fluid, in this size range has never been constructed. In addition, there are many uncertainties, as you can imagine, with regard to operation and maintenance, annual energy production, receiver reliability, and on and on, that makes the project certainly very challenging and not without risk.

The plant represents, as I mentioned, in our opinion at least, a forerunner of a different class of plants that can, relative to Solar I, achieve very high efficiencies, that can have somewhat simplified operating scenarios, and that can meet intermediate if not quasi-baseload load demands through the incorporation of large amounts of storage. That is also true of the salt-type concept that Frank Duquette mentioned.

The time schedule on which this project is proceeding at Carrisa Plains is extremely critical to its success. Financial considerations have dictated a goal of achieving some power delivered to the grid by the end of calendar year 1986. This necessitates the beginning of long-lead procurement by late this year and site construction by early 1985, since the total fabrication and construction is on the order of 2 years.

It is important to emphasize that the construction time for this plant is such that decisions for proceeding must be made within the next 6 months if we are to meet that required deadline. These construction times will be typical, I think, of large central receiver plants of this type. It is this constraint that is the basis for our position, and action on the Federal tax credit must be taken within the next 6 months if this project, or any other project of this particular type and in this time frame, is to be successful. The amount of capital required is such that an individual company or group of companies cannot afford to go at-risk to that level, and I will talk about that in just a minute.

The selection of 30-megawatt power level for the plant is based, in part, on minimizing the total capital cost. Give the fact that this is one of the first attempts to put together a third-party solar central receiver project under private-sector economic constraints. Investment bankers have suggested that unusual commitments are probably going to be required in offering this in the marketplace. In addition to an equity position, a firm fixed price, and some probably nonstandard warranties may be required on the part of major participants. The smaller the overall project cost, in our opinion, the more likely we are to obtain these particular commitments.

Financial constraints are certainly the most important issue facing the Carrisa Plains project in particular. The most important factor in that financial picture is, of course, the capital cost. Although final cost numbers have yet to be developed under the final design that we are cost-sharing with DOE at the present time, we expect it to be somewhere on the order of $150 million, with $125 million of that being the actual capital cost and the balance being brokers' fees and interest on construction and things like that.

So in spite of the improvement in cost relative to Solar I, as you can see, it is about the same capital cost as Solar I but three times the power level. The Carrisa Plains plant will not be economically viable without Federal and State tax credits and without some help from the California Public Utility Commission, in terms of nonstandard power sales agreements and a financial package, given the current price of fuel and the estimate of the way it will escalate.

To give you some idea of the economic problem facing us here, if the revenue from the sale of electrical energy is based only on a currently-approved standard avoided-cost offer, and we have in the 15 percent tax credit and a 10 percent ITC and State tax credits as modified by the Federal one, then the project has a shortfall of about $40 million. Nevertheless, if a reasonable PUC-approved package can be worked out and tax credits can be taken, one investment broker has stated that the project probably can be sold if the major participants provide such features as I mentioned a minute ago, on fixed pricing, special warranties, and the like.

So you can see that the financial equation for Carrisa Plains is a very delicate one and requires some risk-taking on the part of all concerned—the participants, the ratepayer, and the taxpayer. Other proposed central receiver projects are in a similar position, I think. Each may require some direct Federal assistance in the construction phase for a specific high-risk component. For example, the receiver at the top of the tower at Carrisa Plains or another project like that could be supplied, in our opinion, by the DOE and help us get across this delicate financial situation that I mentioned. That is the portion of the solar thermal budget that this particular project could use.

The issues then that must be addressed to bring the Carrisa Plains project to fruition are that the total project costs must come under a cap of about $150 million, and we believe at this point that it will; and that Federal and State tax credits must be available, at least through 1987, and some action extending that Federal credit must be taken by approximately mid-1984, within 6 months or thereabouts; and the California PUC must approve some kind of nonstandard financial package approximately in the same time; and the major participants must be willing to consider these special types of warranties.

The question naturally arises, in our opinion at least, if the Carrisa Plains project is not economically viable, how can it contribute to achieving economic viability in a free market environment. Those who are involved in the manufacture and construction of these types of plants are generally agreed that economic viability without tax credits must be achieved within a reasonable timeframe in order to justify our commitments to these projects.

We believe, therefore, that it is reasonable to expect that such viability can be achieved. The Carrisa Plains project will serve to demonstrate full-system performance in terms of reliability, availability, and those types of factors. We especially hope to substantiate our predictions of operating and maintenance cost as it applies to future plans.

Most importantly, by verifying the technology of all liquid-type plants, such as the sodium and the salt, the Carrisa Plains plant, along with Solar I, will give to the investment bankers, to potential investors, to manufacturers, utilities and other interested parties confidence in the economic potential of this type of energy system.

We believe that economic viability is achievable through economy of scale, through improved performance, through low-cost high-capacity storage systems, and through the production of larger numbers of plant components. We visualize the Carrisa Plains as the logical systematic next step after Barstow in the construction of plants incorporating those improvements that I just mentioned. At least one economic assessment that we have done shows that a 100-MW electric plant, incorporating reheat, incorporating the air-rock type of storage that we are particularly interested in, heliostats at $125 per square meter, would produce energy at less than or equal to that from a coal plant, if the coal plant costs $1,200 per kWe and the price of coal was $1.50 per million Btu, excalating at a real 1.3 percent per year.

So it looks attainable, in our opinion, that those assumptions are not too unrealistic. However, the attainment of some of the abovelisted improvements will need continued involvement by the Government in research and development of solar thermal systems in general and solar central receivers in particular. Obviously, this development work fits in DOE's category of high risks, not only because of costs but also because of complexities and uncertainties, and the sequence of events that must occur to get the Carrisa Plains-type plant in particular online, and to proceed with follow-on units incorporating step-wise improvements.

Three to five follow-on plants may be necessary to achieve the ultimate goal of economic viability without tax credits. We expect that each successive plant will require less Federal involvement or no Federal involvement in plant construction.

In conclusion, let me say that the Carrisa Plains project may need to compete with other promising projects for additional direct assistance under the solar thermal proposed budget category entitled "Large-Scale Experiments in Direct Support of One or More Individual Projects." The solar thermal budget recommendation for this category is $10.3 million.

The ultimate success in achieving economic viability in a free-market environment definitely, in our opinion, depends on some Federal R&D assistance in the solar thermal budget category entitled "Subsystem Development." The solar thermal recommended budget in this category is $6.5 million, and we would expect to compete with other viable systems for those funds as well.

Finally, the Carrisa Plains project and other projects like it can be expected to benefit from general R&D in the areas of materials and controls and improved solar collectors. It is also essential that the Solar I plant continue to operate and that the CRTF continue to be available.

Thank you very much.

[The prepared statement of Mr. Springer follows:]

STATEMENT OF

THOMAS H. SPRINGER

VICE PRESIDENT

SOLAR ENERGY INDUSTRIES ASSOCIATION
ON
BEHALF OF THE SOLAR THERMAL DIVISION

BEFORE THE

SUBCOMMITTEE ON

ENERGY DEVELOPMENT AND APPLICATIONS

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

MARCH 1, 1984

# THE CARRISA PLAINS SOLAR CENTRAL RECEIVER PROJECT

TESTIMONY BEFORE THE HOUSE SUBCOMMITTEE ON
ENERGY AND APPLICATIONS
MARCH 1, 1984
by
Solar Thermal Division
Solar Energy Industries Association

I am Tom Springer, Program Development Manager of Solar Energy Systems at the Energy Systems Group of Rockwell International in Canoga Park, California. Thank you for the opportunity to provide this testimony in support of the Fiscal Year 1985 budget being proposed by the Solar Thermal Division of the Solar Energy Industries Association. As a member of the Solar Thermal Division and as Vice President of the Association, I am pleased to be able to speak to you briefly on this subject from the standpoint of participation in a specific solar thermal project that is currently in the final design stage. I would like to show how this project, as well as future projects, may depend upon the continuation of reasonable Federal support for solar thermal technology research and development. In addition, although it does not fall directly under the purview of this Subcommittee, I would like to indicate how this specific solar thermal project depends upon the Federal energy tax credit and upon some action being taken within the next 6 months to extend the current credit expiration date of December 31, 1985, or provide some sort of affirmative commitment.

The specific solar thermal project to which I am referring is a 30-MWe solar central receiver concept called the Carrisa Plains Power Plant. The concept is similar to that of the 10-MWe Solar One pilot plant located near Barstow, California. The Carrisa Plains plant can serve as the next evolutionary step in progressing from the largely government-financed Solar One to the large-scale, totally private-sector-financed commercial plants of the future. We view it as a precommercial plant that we hope to finance largely from the private sector under rules and constraints applicable to private sector undertakings.

As I mentioned, we are in the final design stage of the project. The final design task is being conducted under a cooperative cost-sharing agreement with DOE. The participants are Arco Solar Industries, a division of Atlantic Richfield Company; Bechtel National, Inc.; Pacific Gas and Electric Company; and the Energy Systems Group of Rockwell International. Concurrently with the final design work, the four companies are funding, independently of the Federal government, an effort to structure a third-party venture to finance construction of the plant, to acquire construction permits, and to develop an acceptable, nonstandard power sales agreement for submission to the California Public Utilities Commission.

As you probably know from your familiarity with the Solar One plant near Barstow, the solar thermal central receiver concept consists of a tower surrounded by, or adjacent to, a field of mirrors, called heliostats, which track the sun and direct its image onto a receiver component located on top of the tower. The proposed 30-MWe plant is a size that would supply enough energy to meet the needs of about 12,000 typical U.S. homes and would displace approximately 160,000 barrels of oil annually. The tower will be about 470 feet in height and will be placed at the south end of a fan-shaped field containing about 1,900 heliostats each 1,000 square feet in area. The plant will occupy about 300 acres of ground, including the heliostat field, and will measure about 3,600 feet from the base of the tower to the outermost heliostat and about 4,600 feet at the widest part of the fan-shaped array. Enough storage will be provided to allow the plant to operate at full power without any solar input for a period of 70 minutes.

The Carrisa Plains site is located about 50 miles east of the city of San Luis Obispo and about 40 miles west of Bakersfield, California, in an area serviced by Pacific Gas and Electric Company. A 115-kV transmission line passes near the site on which the plant is expected to be located. The Carrisa Plains is a sparsely populated, enclosed, flat valley at an elevation of 2000 feet. The solar energy received, although probably not as high as that of the Barstow plant, is very promising.

Whereas the Solar One plant employs water as the heat transport fluid, the Carrisa Plains plant is being designed to utilize liquid sodium metal for that purpose. Sodium has extremely good heat transfer properties that will allow selected components, particularly the receiver at the top of the tower, to be small in size. Additionally, sodium technology has been well established by over 30 years of research and development work carried out principally by the Federal government. Except for the receiver, all the heat transfer system components that are being specified for Carrisa Plains have already been built in similar versions whose sizes exceed that of any that will be needed even for commercial-size solar plants. Furthermore, many of these components have been operated at temperatures well in excess of those contemplated for this plant or subsequent larger ones. In short, we are drawing upon and intending to apply a technology in which the Federal government has already invested a few billion dollars. The properties of the fluid are extremely well known; the compatibility of the fluid with common materials of construction is well established; hundreds of thousands of hours of operating time have been accumulated on large-scale, high-temperature systems; large components have been designed, tested, and operated; and moderate-size power plants using the fluid have been designed, built, and operated.

The receiver component, although at a far lower level of maturity, has been developed to some extent. Rockwell, using discretionary resources, designed and built a three-panel prototype receiver unit that was successfully tested, in cooperation with DOE, at the Albuquerque central receiver test facility a year or so ago.

Although, as stated, most components in the heat transport part of the plant are fully developed, a complete solar-type system using liquid sodium as the heat transfer fluid in this size range has never been constructed. In addition, there are many uncertainties--with operation and maintenance costs, with operation strategies, with annual energy production, with receiver reliability, and with plant availability and maintainability--that render the project challenging and not without risk.

As I have stated, we feel that the Carrisa Plains plant is the logical evolutionary next step relative to Solar One. Unlike Solar One, the Carrisa Plains plant suffers no thermodynamic penalty when operating from storage. In fact, this plant, like other all-liquid-cooled concepts, operates from storage at all times and thus has the operational advantage of having the steam-producing side of the plant isolated from the solar-collecting portion. Also, we expect to find a significant lowering of the cost of producing energy since the Carrisa Plains system is more efficient over a daily cycle than that of Solar One, and its capital cost will be about the same as that of Solar One even though the power output is three times as large.

These statements should not be construed, incidentally, as an indication that the water-steam concept has no merit. For a utility that wants little or no storage and does not require reheat cycles, the water-steam concept may be the most cost-effective way to proceed for specific load-demand scenarios. It must be emphasized, furthermore, that the Solar One plant, being an experimental pilot plant, does not necessarily represent the ultimate in the state of the art. Solar One has been, is now, and, we hope, will continue to be the "flagship" of the solar central receiver technology. It is an extremely important tool in the development of the technology and in verifying the feasibility of central receiver concepts to the venture and utility markets. The Carrisa Plains plant, on the other hand, represents the forerunner of a different class of plants that can achieve very high efficiencies; that can have somewhat simplified operating scenarios; and that can meet intermediate, if not quasi-base-load, load demands through the incorporation of large amounts of stored energy.

The time schedule on which the project is proceeding is extremely critical to its success. Financial considerations have dictated a goal of achieving some power for delivery to the PGandE grid by the end of calendar year 1986. This date necessitates the beginning of long-lead procurement by late 1984 and site construction by early 1985 since total fabrication and construction time is about 2 years. The final design under the DOE cooperative agreement was begun in November 1983 and is expected to be completed by January 1985. Thus, there may be some overlap between the end of final design and the beginning of some fabrication work. It is important to emphasize that the construction time for this plant is such that the decision for proceeding must take place within the next 6 months if we are to meet the required deadline. These construction times will be typical of large central receiver plants. It is this constraint that is the basis for our position that action on the Federal tax credit must be taken within the next 6 months if this project, or any other project of this type, is to be successful. As I will indicate shortly, the amount of capital required for these types of plants precludes corporations from proceeding until the tax credit issue is resolved.

The rationale for selecting a 30-MWe power level for the Carrisa Plains plant has frequently been questioned. Why not, for example, proceed directly to a commercial-size unit? One reason for selecting this power level is that it falls within PURPA guidelines and is, therefore, exempt from a number of Federal and State regulations that could significantly increase cost and construction time. Secondly, the total capital cost is much more manageable, given the fact that this is one of the first attempts to put together a third-party, solar central receiver project at this dollar level. In addition, investment bankers have suggested that some unusual commitments may be required to sell the offering in the venture market place; for example, in addition to an equity position, a firm fixed price and some probably non-standard warranties may be required on the part of the major participants. The smaller the overall project cost, the more likely we are to obtain these commitments. In other words, since this will be one of the first attempts to market a solar central receiver under private sector economic constraints, the risks will be high; therefore, the lower we make the risk exposure the more successful we are likely to be. Some other considerations bearing on the size selection are (1) the availability of some existing sodium component designs with well established performance records; (2) the conservative use of sodium technology (1050°F versus 1100°F); (3) a modest scale-up relative to Solar One (factor of 3); and (4) a reasonable scale-up of the receiver component, which is the least well known of all the components and will be subjected to the most severe operating conditions.

Financial constraints are the most important issue facing the Carrisa Plains project. And the most important factor in the financial picture is the capital cost. Although final capital cost numbers will be one of the products of the final design task, we feel that it will be around $125 million. When one adds interests for construction loans, brokers' fees, and other costs, the total comes to about $150 million for the 30-MWe plant with 70 minutes of storage, a storage size which yields a capacity factor of about 0.3. By comparison, Solar One at 10 MWe and a capacity factor of about 0.34 had a price tag of about $140 million--a value that is probably very reasonable, incidentally, for a first-of-its-kind, pilot-type plant. In spite of the improvement in cost, the Carrisa Plains plant will not be economically competitive without Federal and State tax credits and without some help from the California Public Utilities Commission in terms of a nonstandard power sales agreement and financial package, given the current price of fossil fuel and its currently projected price escalation. To give you some idea of the size of the economic problem, however, if the revenue from the sale of electrical energy is based only on a currently approved standard avoided-cost offer, with 15% Energy Tax Credit, 10% Investment Tax Credit, and 25% State credits, then the project has a shortfall of about $40 million. Nevertheless, if a reasonable, PUC-approved package can be worked out and tax credits can be taken, one investment broker has stated that the project can probably be sold if the major participants provide such features as a fixed price on the plant, an equity position, and some type of completion and performance warranties. Thus, one can see that the financial equation for the Carrisa Plains project is a very delicate one and requires some risk-taking on the part of all concerned: the participants, the rate payer, and the tax payer. Other proposed solar central receiver projects are in a similar position. Each may require some direct Federal assistance in the construction phase for specific, high-risk components. For example, the receiver at the top of the tower and the steam generators could be supplied by DOE in return for long-term data on operating costs and performance. Steam generator data could be of benefit to other DOE programs as well.

The issues, then, that must be addressed to bring the project to fruition are (1) the total project must come under a cap of about $150 million; (2) the Federal and State tax credits must be available at least through 1986, and action extending Federal credits must be taken by mid-1984; (3) the California PUC must approve some kind of nonstandard financial package by mid-1984; and (4) the major participants must be willing to offer some special types of warranties and guarantees. There are, of course, some standard types of problems, such as an environmental impact report and construction permits, that must be solved as well.

The question naturally arises: if the Carrisa Plains project is not economically viable, how can it contribute to achieving economic viability in a free-market environment? Those who are involved in the manufacture and construction of solar central receivers are generally agreed that economic viability, without tax credits, must be achievable within a reasonable time in order to justify their participation in near-term, noncommercial projects. They believe there is a reasonable expectation that such viability can be achieved. The Carrisa Plains project will serve to demonstrate the full-system performance in terms of reliability, availability, and maintainability. We hope it will substantiate our operating and maintenance cost projections for future plants. Most importantly, by verifying the technology of the all-liquid-coolant-type plants, the Carrisa Plains plant, along with Solar One, will give to investment bankers, potential investors, the manufacturers, utilities, and other interested parties confidence in the economic potential of this type of energy system.

We believe that economic viability is achievable through economy of scale (the plant optimum size is about 100 MWe); through improved performance (adding reheat to a Carrisa Plains-type plant and increasing operating temperatures will improve efficiency); through low-cost, high-capacity storage systems (concepts such as air/rock storage for quasi-base-load operations appear to be feasible); and through the production of larger numbers of plant components. We visualize Carrisa Plains as the logical, systematic next step after Barstow in the construction of plants incorporating these features. At least one economic assessment has indicated that a 100-MWe solar central receiver, incorporating a reheat cycle, air/rock storage, and heliostats at $125/m^2$, will have a busbar energy cost less than that of a coal-fired plant if the coal plant costs $1200/kWe and if coal costs are $1.50/MBtu escalating at a real 1% a year. The latter assumptions are, I think, reasonably conservative. However, the attainment of some of the above-listed improvements will need continued involvement by the Federal government in research and development of solar thermal systems in general and solar central receivers in particular. Obviously, this development work fits in DOE's category of high risk, not only because of cost but also because of complexities and uncertainties in the sequence of events that must occur to get a Carrisa Plains-type plant on line and to proceed with follow-on units incorporating step-wise improvements. Three to five follow-on plants may be necessary to achieve the ultimate goal of economic viability without tax credits. We expect that each successive plant will require less Federal involvement--or no Federal involvement--in plant construction.

In conclusion, let me say that the Carrisa Plains project may need to compete with other promising projects for additional direct assistance under the STEA proposed budget category entitled "Large Scale Experiments in Direct Support of One or More Individual Projects." The STEA recommendation in this category for FY 1985 is $10.3 million.

Ultimate success in achieving economic viability in a free-market environment definitely depends on some Federal R&D assistance in the STEA-proposed budget category entitled "Subsystem Development of Second Generation Receivers, for a Reheater, and for Air/Rock Storage." The STEA-recommended budget for this category is $6.5 million for FY 1985. Other concepts will also be depending on some assistance within this budget figure. Finally, the Carrisa Plains project and other projects like it can be expected to benefit from general R&D in the areas of materials, controls, and improved solar collector concepts. It is also essential that the Solar One plant continue to operate, principally as a power producer, and that the CRTF continue to be available so that improved components can continue to be developed and tested under actual solar conditions. The STEA-recommended solar thermal budget for FY 1985 is, I think, a reasonable one that recognizes our need to reduce Federal spending, has a minimum mortgage, and yet maintains a viable technology in which a substantial investment by the government has already been made. The industry is very appreciative of the budget figures that have been provided by this Subcommittee in the last few years. They have been somewhat less than we might all have liked but appropriate in the austere environment that we face.

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Mr. **Bateman**. Thank you very much, Mr. Springer.

At this time, I would ask if our next witness, Mr. Fred Goldsberry, the chief engineer of Zapata Exploration Co. of Houston would make his statement. Bear in mind, Mr. Goldsberry, that your full statement that you have presented to the committee will appear in the record, and so you may summarize or deal with it however you feel best.

## STATEMENT OF FRED L. GOLDSBERRY, CHIEF ENGINEER, ZAPATA EXPLORATION CO., HOUSTON, TX

Mr. **Goldsberry**. What I would like to do is to deal with my statement directly and succinctly. The reason that I am here this morning is not because I am looking for money to support something that Zapata is doing. We are an independent oil and gas company and a drilling contractor.

My interest in this particular program stems from the fact that for 4 years I directed the operations of that program in Houston, TX, under a rather unusual arrangement with the Department of Energy. These types of budget proceedings are something with which I have not been connected to a great extent in the past. I think my written statement pretty well summarizes my feelings on where this resource stands in relation to our national energy problems and to the Federal budgeting process.

Mr. **Bateman**. Mr. Goldsberry, do I understand correctly that you are the source of these interesting little vials?

Mr. **Goldsberry**. Yes, sir.

Mr. **Bateman**. Would you take a minute, before I turn back and ask Mr. Glover for his statement, to tell us what we have and what is significant there?

Mr. **Goldsberry**. The bright yellow specimens—I hesitate to use that word in many cases—are condensate samples that were recovered from steam drips—in other words, a steam separator on one of these geothermal wells. The brine that we are producing is really the same brine that you would find associated with conventional oil and gas deposits. By flowing a well that is principally brine, we are able to detect some rather interesting things going on in Mother Earth, some things that we did not understand.

What you are holding in your hand is paint brush cleaner. It is a relatively pure solvent that is composed of aromatic compounds that are probably selectively trapped in bounding shales or in the sandstone. When you consider the amount of this material, this is very diffuse in the Earth, but it should be everywhere. We tested four out of four wells and found it present.

To me, this is a startling discovery. It leads us into arguments over the origins of hydrocarbons, and this has been a very sensitive political issue in the oil industry for a number of years. You have a group that goes about the country saying that hydrocarbons are very rare and precious things, and you have other people saying no, the solar system is absolutely lousy with hydrocarbons, and it is a miracle that we have an oxygen atmosphere on this planet.

The point is that we have come up with something that is very unusual. What we are dealing with in this program is pulling together the continuum of the spectrum of oil and gas. Oil and gas are legal definitions, not physical definitions. As it turns out, we deal with research in a number of interesting and separate areas. Area No. 1 is conventional oil and gas. We call this fossil energy. We do not even know for sure that it is fossil, but we call it that. Area No. 2: We deal with so-called enhanced production or secondary recovery projects.

What you are holding in your hand is the result of a tertiary recovery process. This is a process that would occur after you have used up all the free hydrocarbons in nature. Now you have to start dealing with those that are soluble or dissolved in salt water. All of the sediments in the Earth contain salt water. The geopressure geothermal program is something of a hybrid because we are dealing with water at great depth that has been heated to temperature so that the resource is really 50/50 hydrocarbons and geothermal or thermal electric in nature.

This leads us to what I think should be the guts of my testimony. The geopressure program, in the course of testing some oil and gas wells, discovered an oil well by flowing brine at high rates. This is the future of the petroleum industry in this country. If we can solve the water production problems of geopressured geothermal, we can handle all of the water production problems associated with conventional hydrocarbons.

In 1980, during the Presidential campaign—so I guess that is why we did not get a lot of attention—we tested an abandoned oil and gas well that had been drilled by Lear Petroleum. We took the well over with the idea of testing it for salt water. By all standards of the industry, we had three and in many cases four or five opinions stating that well is a dry hole; there is nothing down there but salt water. We drilled a disposal well, flowed the well for a week, and at the end of the week began producing hydrocarbons.

It was embarrassing. We looked around for 2 days, looking for a hydraulic leak and finally determined we were producing way too much condensate to be accounted for. The point is that we discovered an oil well. We turned the well back to Lear Petroleum because they had the hydrocarbons lease and we did not.

The long and the short of it is, that well has produced to this date 42,000 barrels of condensate and almost four-tenths of a billion cubic feet of gas. It is still cranking along just fine; they have no intention of plugging it. But it is being produced under a very unusual arrangement. To get 42,000 barrels of oil, we had to produce 1.6 million barrels of salt water. This is under pressure. We call this type of process coproduction. The Gas Research Institute has aimed its resources at this particular area.

The point I am trying to make by this is, you cannot sit down and separate one area of hydrocarbon or, for that matter, geothermal endeavor from the other. This is so for the geopressure geothermal program as it is with the hydrocarbons program, yet the organization of the program is somewhat strange.

Now, let us get to budget issues. All of us like to get bargains. I love a bargain, and I am sure you do, too. DOE loves bargains. Sometimes they imagine bargains. In the case of the geopressure geothermal program, I think imaginations have been running amuck for sometime. When you go out to drill an oil well, this is a big boy's game: you lay your money on the table, and you take your chances. That is true for any drilling operation. In the case of DOE, there has been a tremendous amount of wishful thinking, not generated in the field but generated, let us say, in unspecified places.

They try to take an endeavor that was designed for a $40 million per year budget and crunch it down into a $5 million budget. I am not getting specific on their numbers, but this in relative terms is what has happened. We still have three fairly expensive wells, two of which should continue to be produced.

There is another item up there on the table. It is a nozzle. It is coated with scale. Right now, the Department of Energy has two design wells that have a coating like that from top to bottom. I know where you can get 30,000 feet of pipe that is coated just like that. We know how to keep the scale off our surface equipment, but it is necessary to understand how you keep the scale off the tubing. No oil man with good sense is going to go out and drill a well and try to produce it if that is going to happen to it.

The scale was formed on one of the wells in a period of about 90 days. So here we are faced with a situation where to put those two wells back in operation, it is going to cost about $2.5 million, provided the wind does not shift while the operations are underway. You are talking about lifting 300,000 pounds of pipe out of a hole that probably has another 200,000 pounds of scale on it. You do not go after that with a light work-over rig. You put the big machinery on it, and you do the job right. You do not cut corners.

You have pressure down there. This is like having a water balloon with a brick sitting on it in front of you. You would not sit there and poke it with your pencil; you would expect to get wet. A geopressured well is just this type of situation. As you get deep enough in the Earth, the water at depth is at geopressure. The weight of the rock is pressurizing the water. It has been sealed off by many layers of shale.

So now we are left with a DOE budget—I am not sure what they are proposing but let me tell you what they should have proposed to finish the job. We have a well south of Houston called the Pleasant Bayou. The Electric Power Research Institute has expressed interest for some time in putting an electric power plant on that well. That well is down right now because of scaling problems. It needs to be put back on line, which will cost about $2 million, and I would assume that there would be $2 million worth of problems in some form that will occur. This is only realistic.

There is another well, the Gladys McCall, south of Lake Charles. The Gladys McCall is going to need retubing. We have a well over at Sweet Lake. It has not been as successful as we would like. I have submitted a statement as part of the testimony that was generated by a group of my peers in the oil and gas business, some of them involved in research and some of them just interested. But it will give you an idea of a cross-section of what those people think, as far as the Sweet Lake well is concerned.

There is another well that has fallen into our lap as a result of the wells of opportunity program several years ago. That is the Superior Hulin well. We tracked that well in 1980 and 1981 while it was being drilled. It since has been drilled and depleted. The well goes to a depth of over 20,000 feet and represents a tremendous opportunity to test this type of resource vertically. We have tested it horizontally at a depth of about 14,000 feet all across the gulf coast. Now it is important to see how does the condensate presence change with depth. Does our gas saturation or salinity change with depth? There are a lot of things that people think they know that they really do not. This program has discovered a number of them, and some of those things are sitting on your table this morning.

I believe that pretty well concludes what I have, and you may have some questions.

[The prepared statement of Mr. Goldsberry follows:]

Prepared Testimony of
Dr. Fred L.Goldsberry
Subcommittee on Energy Development and Applications of the
U. S. House of Representatives Committee on Science and Technology

March 1, 1984

Mr. Chairman and Distinguished Members of the Committee:

This opportunity to testify as to the progress of the Geopressured Geothermal Program is most appreciated. It is a key part of a larger natural gas problem facing our country. In preparing this testimony it occurred to me that perhaps I could bring to this hearing a unique perspective on the position of the Geopressured Geothermal Program in the energy picture of the United States. My engineering background has found me involved in engineering and management positions in rocket motor development, petrochemicals, oil and gas exploration, gas pipelines, geothermal energy and nuclear waste. My employers have ranged from grovernment through utilities to free market organizations. My views on many energy issues were development on both sides of the coin and the edge. Perhaps I can be used today to communicate some concepts.

The Geopressured Geothermal Progam may be one of the more perplexing efforts under the cognizance of this committee. The Geopressured Geothermal Resource is not a destination as much as the cross roads of natural gas and geothermal technology. The most fruitful way to convey the location of this intersection is to look to history and our economic development.

Our nation began as an agrarian society. We developed into an industrial power from the American Civil War until World War I. Agriculture yielded to coal, steel production, and manufacturing derived from these as the economic base for the country. By the Great Depression, natural gas and materials made from it began to appear. They steadily displaced coal for fuel and steel in manufacturing. World War II hastened the shift to synthetic fibers, plastics, and rubber made from natural gas. Natural gas fueled and was the basic material of construction for the post war economic boom.

The economic foundation of our society in the United States is based upon natural gas. We are dependent upon natural gas for our daily existence. Those on the lowest rungs of the socioeconomic ladder are more affected by supply problems than those on the upper rungs. It is the material fulcrum upon which our economic and social balance beam rests. We are discussing our national means for survival.

Our food is grown almost entirely with ammonia, which is made exclusively from natural gas.

We wear clothing made from synthetic fibers, all of which originate as natural gas fractions.

We live in shelters made of concrete, bricks, and glass, which are made in processes requiring fuel gas.

The cars that brought us here are composed of glass, carbon black, rubber, and plastics that are manufactured by processes for which there is no alternative to natural gas.

A large portion of the gasoline for our cars comes from liquids condensed from natural gas streams.

We heat and light our homes with natural gas, directly in the form of fuel gas and indirectly in the form of electricity.

We defend ourselves with natural gas. High explosives and rocket propellant are made almost exclusively from products made from natural gas.

We as a people have built a civilization upon the light hydrocarbon molecules found in dry natural gas. There is no alternative for it in many critical applications and processes. Disrupt the supply and industry as we know it cannot function. Until the present, the U. S. has had to import only oil to meet our energy shortfall. The shortfall was motor fuel, not the chemical feed stocks used to make materials for construction. The so called energy crises was nothing more than a 2 to 5% shortfall in motor fuel supplies.

Gas is the substitute for many other fuel supplies. The converse is not true. Consider the spending levels for research into the origins, resources, and production of natural gas. Gas is becoming more difficult (and hence costly) to find. Our ability to deliver gas from our known reserves is declining as we speak. We cannot meet the overall demands from gas supplies today that we could two years ago. Our reserves of gas are declining in spite of strong gas price increases in the past ten years. Here are some facts of which you should be aware:

We don't understand the origin of natural gas. It may be derived from geologic as well as organic sources. This is rather important if you are in the business of looking for it.

We do not fully understand the mechanics of gas (or oil or water) production. We have theories on rock compressibility, and the pressure resistance to gas flow through the pores in the rock. The theories are linear and elastic. Unfortunately, no one told the rocks or the fluids contained in their pore spaces. They appear to behave in a nonlinear manner. Ultimate recoveries in the geopressure gas resources are uncertain.

Man controls the use of natural gas. He does not control its distribution in nature. If man intends to have anything to control he must first study the distribution of gas in nature and develop the tools to locate and produce it.

Geopressured geothermal resources cover those gas saturated waters trapped and buried at depth. By virtue of this geologic incarceration they are heated by the core of the earth and are saturated with natural gas. The gas content is a function of temperature and pressure. The deeper the brine is buried the more energetic it becomes. It is higher in pressure and hotter, which allows it to have a greater gas saturation per unit volume.

In a practical sense a gas well is one completed in the free gas bubble formed by gas in excess of saturation. In the reservoir, the brine is the geopressured geothermal resource. Most of the gas that exists is dissolved in the brine. A much smaller portion is found in free gas deposits. As the gas is produced, some is bypassed by brine. It can be recovered only by the continued production of brine after the so called dry gas well has watered out. This secondary gas recovery process is called Coproduction. The gas recovered is the same in all three cases. The free gas is the lowest cost (most profitable) but is the most difficult to locate. (One try out of seven). Coproduction gas occurs in reservoirs already found. Geopressured Geothermal is easier to locate because of the size of reservoirs. (Three out of four tries). The beauty of the gas Coproduction and geopressured geothermal resources is that they represent fall back positions for what the industry calls a "depleted reservoir" or "a dry hole." The Geopressured Geothermal Program of the Department of Energy and the Coproduction Program of the Gas Research Institute deal with understanding the resource mechanics and production techniques associated with large volume brine production and disposal. The gas exploration industry plugs wells as soon as they begin to produce significant quantities of water, not when the reservoir is fully depleted.

The orientation of the petroleum industry is to explore for and produce free hydrocarbons. The exploration is accomplished by Independent Oil Companies, who are generally small operators with limited budgets. The Major Oil Companies should be viewed as energy banks. They hold the leases, control refining, transportation, and marketing. The situation is analagous to farming. The independent is the family farmer, the major is the landowner and banker. The independent acquires his leases in many cases in a sharecropping arrangement not surprisingly called a "farmout."

The Independents' job is to look for deposits of free hydrocarbons. His business is speculative enough without adding R & D to his risk portfolio. The Major Oil Companies conduct exploration programs but in general look for the big prospects and big money projects. They have their own Laboratories to develop information. But that data is not available to the small producer. Yet, it is the small operator who finds most of the oil and actively pursues the innovative ways of recovering hydrocarbons. Data bases and how to technology are vital to a competitive petroleum industry. The legitimate Federal role is to provide that data.

## Geopressured Geothermal Energy Program Results

The geopressured geothermal resource consists of deeply buried alternating layers of sealing shale and brine saturated sandstone that contain heat and fluids near lithostatic pressure. The largest and most accessible deposits occur beneath continental shelf and onshore of the northern Gulf of Mexico. The U. S. Department of Energy has been conducting an exploratory drilling and hydrocarbon extraction experimentation program in Texas and Louisiana. Along with the heat and hydraulic pressure contained in these brine deposits is a significant quantity of natural gas. Prior to the testing of seven oil and gas wells for salt water chemistry and four wells designed for large-volume brine production it was believed that one would encounter formation waters both saturated and undersaturated with hydrocarbons relative to in situ temperature, pressure, and salinity. The objective of this exploratory drilling program was to sample the hydrospectrum and to develop techniques for producing the resource and disposing of the brine. It can also affect the way we look for conventional oil and gas deposits.

The findings of this program have differed from expectations. The following items represent changes in the general perceptions of the resource.

1. Extensive brine reservoirs exist in conjunction with the expected small-sized reservoirs normally found on structure in the course of oil and gas drilling.
2. The permeability of these reservoir rocks to brine is typically three to five times greater than that expected for gas bearing sandstones.
3. All brines tested thus far have been at, or near saturation insofar as recombination studies can determine.
4. The presence of liquid and excess hydrocarbons has been more prevalent than expected by the industry. As brine is produced one can expect the apparent ever increasing production with time of an oily condensate composed of benzene, toluene, and xylenes. These are commercially valuable solvents that may also act to facilitate the natural formation of hydrocarbons from organic matter buried in sediments. They may function in nature much as they do in the synthetic fuels processes that are used to convert organic waste to oil and methane gas. Areas that have been ignored for years because they lacked organic rich source beds of sufficient quantity may become targets for exploration. These condensates may be associated with the bounding shales. Only long term flow testing and laboratory analysis of several wells over long time periods can resolve this issue.
5. The disposal of salt water into relatively shallow (1,000 m.) sands has been easier than anticipated.
6. Scale and corrosion control has been readily achieved at surprisingly little expense. Work done by Rice University, sponsored by the Gas Research Institute and directed by the U. S. Department of Energy, Geopressure Projects Office, has resulted in effective treating at costs of less than $50.00 per day. Pleasant Bayou No. 2 and Gladys McCall No. 1 are currently experiencing scale problems down hole where treating has not been done.
7. The geopressured geothermal resource is hydrid in nature. It is at the same time and inseparably a combined geothermal electric and natural gas resource.

## National Gas Reserves Status

Today we are facing another great change in our economic and social life. We call it "The Energy Crisis". It has come as a surprise to the general public but was openly discussed in our engineering schools in the 1960's as the big problem for the 70's. Awareness was based upon simple arithmetic. Exponential growth in energy consumption would lead to a cross-over in the stagnant growth of petroleum production that was the result of regulated prices. This would result in our being an importer and therefore subject to the whims of international politics and economics. Our trials and tribulations in the wake of fuel oil shortages will be trivial compared with the plight of this country if hit by a critical shortfall in natural gas supplies. The response to this danger has been to arrange for the importation of natural gas from our neighbors to the north and south. We are now dependent upon them. Efforts to import Liquified Natural Gas from overseas producers have been a business disaster for those involved. The costs in capital and environmental damage from a synthetic fuels industry to meet a natural gas shortage would be staggering. An engineering analysis of the various processes to make end products from coal and tar sands leads one inevitably to the conclusion that it is cheaper and far more efficient to replace our gas-fired industrial capacity with a new generation of coal-fired plants rather than suffer the inefficiencies of coal gassification as an intermediate step. These costs are sufficiently high and the process technology so uncertain that even today's unconventional gas sources will be preferentially produced as a final increment before the conversion to coal derived alternatives will take place. This conversion may occur within the next generation. It will require substantial productivity from our existing industrial capacity to build the new industrial base for the twenty-first century. As we discuss natural gas here today our thoughts should focus upon the words "national survival."

The United States has undergone two major "oil shocks." Both events were followed by periods of abundant fuel supply. The shocks came in 1973 and in 1979. The periods of abundance and slightly declining real prices were 1977 and 1983. This suggests that sometime between now and the end of the summer of 1985 the world will experience another shock. A shock could easily come in the form of an oil price collapse. Such an event would devastate the domestic exploration industry. Our national security would be endangered through unilateral energy disarmament. The policy throughout the life of the Department of Energy has been to bet heavily on nuclear energy research, and to buy oil at retail prices and store it in ways that have left its accessibility in times of national emergency open to question. The pursuit of a coherent policy on energy matters should include a balance on research topics to include technology and resource base information on all potential sources of natural gas. The U. S. Government can develop deliverable energy reserves by buying oil and gas reserves in the ground. At this point the U. S. is doing nothing about Strategic Gas Reserves. Our drilling industry is idled while we enjoy soft fuel markets and warm winters. All the while we are buying foreign oil at retail prices to pump into the ground. Proven petroleum reserves can be had for one third the retail price and are already stored in the natural tanks that have held them for ages. This is not a call for a new program, it is a suggestion for a far more efficient way to accomplish what the nation has committed itself to do. It is the only way to acquire emergency gas supplies. And most importantly it will provide a stable investment atmosphere for the oil and gas industry to explore and produce the marginal and secondary gas supplies. The Research Programs should develop the techniques necessary to produce the secondary supplies.

## Research Organization

Natural gas is a legal term, not a scientific one. When the Almighty hastened mother nature to her task of developing the sediments that make up the traps for hydrocarbons no distinction was made as to oil or gas. In the ground and under extreme pressure we find their physical appearance to be quite similar. The distinction comes in how they are marketed. Gas is moved in a regulated pipeline, whereas oil is carried in tank trucks and ships as well as pipelines. The distribution of gas is best accomplished in a monopolistic utility market. Liquid hydrocarbons are transported in smaller quantities; hence a free competitive marketplace is the more efficient distribution mechanism. The natural gas research programs conducted by the U. S. Department of Energy have been defined on the basis of legal definitions derived from regulated markets rather than on the basis of the continuous spectrum of resources found in nature. The confusion, duplication, and in some cases failure to investigate certain aspects of our nation's petroleum resources may have dire consequences in the future.

The geopressured geothermal resource represents one end of a continuous spectrum. Conventional dry natural gas production is the other. A conventional reservoir is viewed as hydrocarbons and water trapped under pressure in the pore spaces in rock. A hole is drilled into the rock; pressure in the hole is reduced and the fluids begin to move toward the bore hole and capture according to the laws of physics. It is only upon arrival at the surface that the gas molecules are informed of their rights under the Natural Gas Policy Act, certificated and consigned to a pipeline or place of storage until they are consumed.

Research should be organized along the lines of physical laws rather than regulatory laws. As law makers you fully understand the necessity for making our legal system conform to the more fundamental sociological laws that govern our behavior. We call this the art of politics. A program that violates the basic social order and the laws of behavioral science will produce disastrous results. Our concepts of free markets are basically sociological laws. It follows that no business can operate for long with disregard for the laws of supply and demand. A higher law exists in nature. This is the physical law that governs our universe with unerring efficiency. Any endeavor predicated upon violating a physical law will end in failure. Research must be organized along the lines of physical reality, if it is to be successful. The geothermal program and gas programs are "misorganized."

Geopressured geothermal energy resources are as depletable as conventional gas resources. In many cases the same can be said for hydrothermal geothermal. The concept of Coproduction and fall back dry hole production of geopressured geothermal gas and electricity are actually conservation measures to be taken - by the oil and gas industry. This is a renewable resources hearing. Geopressured geothermal resources are not renewables.

Our nation has critical needs for technology to extend the life of our economic machinery and buy time to make a proper selection of future technologies.

## Recommendations for Organization

Provide some degree of balance between long range research areas and technology development areas.

- Long range glamour programs to investigate exotic energy sources eat up lots of money for projects designed to answer questions of choice rather than to solve near term problems. The nation needs TRANSITIONAL TECHNOLOGIES to get us from the realities today to the promise of tomorrow.

- Reorganize the natural gas and geothermal programs into a comprehensive fluid resources program to focus on the mobile energy resources as a whole. Include the broadest based thinking on the possible origin of the resource.

Recommendations for the Geopressured Geothermal Program Objectives

1. Test the Superior Hulin Well in 1985. Conduct research into the variability of hydrocarbon concentrations with depth. Follow up by producing the well (if possible) to gather operational data by selling gas and electric power. Keep two sets of books. If the reservoir is several billion barrels the well might pay for itself. Project cost should be $6 million.
* 2. Proceed to support the proposed EPRI electric generation project at Pleasant Bayou No. 2. Put that well back on line. Sell gas, make power, and make mistakes. The mistakes in operations and design here will increase the chances for the Hulin Project to be profitable. Cost: $2 million per year plus EPRI contributions.
3. Operate the remaining wells in an effort to gain as much data as possible on hydrocarbon compositions. Cost: $3 million.
* 4. Undertake a new program to track industry drilled wells. Make up front payments for flowing samples of brine in short duration sample tests. Continue public meetings to present research data. $2 million per year.
5. Conduct at least two major field tests of Coproduction technology with industry. Two successful projects will spark interest. This is perceived as a high risk game. A couple of money making projects will allay those concerns. Cost: $5 million plus GRI contributions.
* 6. Basic university research and data archiving. Cost: $2 million per year.

* Level of Effort Basic Program

Program Management Suggestions:

1. Program Organization - Maintain maximum management authority in the hands of the field personnel. Operate the program from the region where the work is conducted. DOE should be represented. No contractor can provide this presence.
2. Consolidate all field operations under a single contractor. Provide wide range authority and scope. Compete this contract in FY 85.
3. Require that DOE consolidate the fluid resources programs into a single management organization to include geothermal and oil and gas related research.
4. Assure that sufficient spending authority exists to deal with well problems as they occur. Progress has been slowed in too many instances by "Waiting on Cash" to fix a problem. Some attempts to fix problems within budget have resulted in excessive costs from the remedial work required to repair "the repair job." There is never enough money to do the job right but always enough money to do it over.

## Suggestions for Congressional Policy

The Country needs a policy of balance between near, intermediate, and long term goals. Congress should continue to seek advice from professionals who have no financial gain or political motives. Focus energy programs upon understanding resources and conversion technologies. Set goals - Demand quality documentation at the end of the project.

## Conclusion

Technology developed in geopressured brine production is critical to continued production from existing water drive gas reservoirs as they begin to produce water. Abandonment is largely due to fear of brine disposal costs and environmental red tape. The Wells of Opportunity Program demonstrated the economic benefits of testing dry holes before abandonment by producing formation waters at high rates. A gas well was discovered while flowing brine at 3000 BPD. The Lear G. M. Koelemay by February 10, 1984 had produced 391 million cubic feet of gas and 42,249 BBL of condensate while flowing 1,689,556 BBL of brine to the disposal well. This is an example of geopressured coproduction. The discovery was made in September of 1980 and reported in Drilling-DCW in January of 1981.

Water and hydrocarbon production technology is an across the board problem for all fluid energy resources. Geopressured geothermal represents the limiting case for geothermal and petroleum extraction technology. Geopressured geothermal research wells are unique in that they represent experiments where key production parameters can be held constant. This is exemplified by the discovery of aromatic condensate. This effect would be masked in a hydrocarbon productive well. Corrections to electric log algorithms for brine salinity calculations and rock plasticity models would not be as apparent in conventional hydrocarbon wells. If an operations problem can be solved in a geopressured geothermal well it can be solved for any well.

Geopressured geothermal resources will not be purposefully exploited this century as primary exploration objectives. When discovered in dry or depleted wells they may be profitable at this very moment. The PURPA Legislation has made small scale well head generation achievable. Soaring electric costs in the past four years have resulted in revenue generating capability on par with revenue from gas sales. Only when this technology has been developed can sound business decisions be made.

Mr. **Bateman**. Thank you very much, Mr. Goldsberry. I obviously jumped the gun, and I should have recognized Mr. Glover for his statement, and I will do that at this time.

## STATEMENT OF LYNN GLOVER, McDONNELL DOUGLAS ASTRONAUTICS CO.

Mr. **Glover**. Thank you very much, Mr. Chairman. I also appreciate the opportunity to speak this morning about solar central receiver technology, which represents one of the McDonnell Douglas efforts in the energy field.

I have a couple of photographs here that will illustrate what I will talk about this morning, if the secretary would not mind handing these to you.

The solar central receiver electric power generation technology has the potential for competing successfully in the free market, if a first commercial-scale project can be financed. The central receiver system differs from other solar powered generation technologies by incorporating very efficient thermal energy storage, which allows central receiver powerplants to follow utility load demand during cloud transients and after sunset.

These plants can be effectively located in the Southwestern United States, from Texas to California, and northward from the Mexican border as far as Wyoming, Idaho, and Oregon. McDonnell Douglas has been involved in central receivers for the last 12 years and plans to be a manufacturer of heliostats and to perform systems engineering work. Heliostats are the major equipment item in this technology, as you see in those photographs.

McDonnell Douglas has developed heliostats from an initial 13-square-meter prototype for the National Science Foundation and then later for DOE and its predecessor to the current 95-square-meter commercial-scale, which you see in the illustration labeled Solar 100. McDonnell Douglas is also the design integrator for Solar I, the 10 MW pilot plant using a water-steam receiver design. That is also illustrated in the other photograph. In an operator role, we have supported DOE in this extremely significant proof-of-concept plant, a project in which the government and Southern California Edison and the Los Angeles Department of Water and Power have invested about $140 million to date, with exceptional effectiveness.

This plant has demonstrated the central receiver to be technologically sound and environmentally safe, and it continues to develop important design and operating data while producing net energy to the electrical grid. As a result of this progress, we have seen at Solar I that there is a reasonable prospect for the commercial success of this technology. However, limited continued support by Congress through extension of the renewable tax credit and budget appropriations for high-risk experiments are still essential to achieving timely commercial market acceptance through a demonstration at a commercial size and with system design features that will generate acceptance by the electric utility industry and the investment community.

As an example of how this would be achieved, McDonnell Douglas is considering the construction of a first commercial-size central receiver in southern California. The proposed project would be a 100 MW plant that is 10 times the size of Solar I and would incorporate new design features and technology required for a central receiver system to compete with conventional power generation technology. This is at a site owned by the Southern California Edison Company.

We have concluded that 100 MW represents an economically viable commercial size, which has the advantages of modularity for convenient and rapid additions to utility capacity. But Solar 100, that 100 MW commercial demonstration plant, would involve significant technology advances and investment to develop a central receiver system design involving a new solar receiver configuration, a very efficient molten salt heat transfer and thermal storage system that has not been used in a powerplant, high-rate production of larger-sized heliostats, and various other equipment which have not yet been used.

There is also an investment risk as long as there is continuing uncertainty over future oil prices. Pioneering utilities, such as Southern California Edison, are seeking third-party help to finance and operate central receiver plants at this time. However, for the magnitude of investment required for a first-of-a-kind project like this, feasibility of financing in the marketplace requires such strong guarantees and promises of return on investment that it is not feasible. Therefore, only partners who have a beneficial interest in the technology, such as the suppliers of solar equipment, may be willing to invest in order to create a future market for their equipment and services. But these suppliers would be taking extraordinary risk to market their products by building a demonstration plant and thus need all the help they can get.

However, the California Public Utility Commission has clearly indicated that they will only approve utility ratepayer support of the Solar 100 project if Federal aid offsets some of the investment risk, because commercial benefits from the central receiver system, through the Solar 100 project, transcend the utility's territory and the State of California.

The central receiver electric power system is not a panacea for America's energy problems. However, commercialization of this technology could displace approximately 800,000 barrels of oil imports each year for each of those 100 MW plants. In addition, plants of this kind provide an environmentally clean source of power, drawing on a permanently renewable source.

Limited support through the DOE budget will allow the Uuited States to maintain an existing world lead in solar technology, exemplified by that Solar I plant, which the Congress and the DOE through their foresight have made possible. Such solar technology will create the opportunity of exporting solar plants on a significant economic scale which will assist the U.S. balance of payments. This demonstration plant and succeeding plants will also each directly create 7,000 man-years of manufacturing, construction, and operating jobs, and these U.S. workers will be employed throughout the country.

In summary, in getting the commercial size central receiver project operating, we will have met the original goals of the government/industrial partnership, working together during the past decade for technology development and transfer to the private sector. The U.S. will have the option of utilizing a clean, renewable energy resource which can benefit many areas of the country, including many places where economic development of the land is not otherwise likely.

Thank you very much.

Mr. **Bateman.** Thank you very much, Mr. Glover.

I will ask the gentleman from New York, Mr. Carney, if he has questions he would like to ask before he has to go. If he does not have to go, would he like to take the Chair, which obviously is his prerogative.

Mr. **Carney.** No; Mr. Chairman. In fact, I would like to make a unanimous consent request that a picture be drawn and hung here among the other great chairmen to signify the job that you have been doing here.

Mr. **Bateman.** Unanimous consent is not given. [Laughter.]

Our next witness this morning is Dr. John T. Whetten, Earth and Space Sciences Division of the Los Alamos National Laboratory. We welcome Dr. Whetten to the panel.

## STATEMENT OF DR. JOHN T. WHETTEN, PROGRAM MANAGER, HOT DRY ROCK GEOTHERMAL ENERGY PROGRAM, LOS ALAMOS NATIONAL LABORATORY, NM

Dr. **Whetten.** Thank you very much, Mr. Chairman.

I appreciate the opportunity to testify before you concerning one of our country's most important energy programs which has promise of delivering large amounts of energy almost anywhere at competitive prices, without sacrificing environmental quality.

The objective of the Hot Dry Rock Geothermal Energy Program is to extract natural heat from the Earth's crust and bring it to the surface, where it can be used to generate electricity, heat homes and greenhouses, process foods and chemicals, and serve many other useful purposes.

In the program to date, we have been successful in the following: One, demonstrating that the resource base for hot dry rock is enormous, virtually inexhaustible, and available in all regions of the country; two, proving the technical feasibility of extracting energy from this resource base; and three, developing the tools, instruments, and other hardware necessary to work at the very high temperatures and pressures with which we are faced to exploit this resource.

In short, the funds that have been made available for the Hot Dry Rock Program are providing for the development of a truly viable and realistic alternative energy source. Although we have had to overcome many technical problems and still face some, we have yet to find technical reasons why the hot dry rock concept cannot be made to work. On the contrary, with each technical accomplishment, we become more optimistic for the overall potential for this program. We are excited about it, we know that the energy industry is interested, and we think that everyone ought to be.

Let me present a small bit of background on hot dry rock geothermal energy. Usefully hot crustal rock exists everywhere beneath the Earth's surface, in most places at depths shallow enough to be reached by conventional drilling equipment. In a few fortunate places, the rock contains sizable hydrothermal reservoirs of natural steam or hot water, but usually a deep hole will encounter only hot dry rock. The goal of the Hot Dry Rock Program is to develop a practical technology for recovering heat from this resource, at a cost competitive with that of heat from more conventional energy sources.

The Hot Dry Rock Program originated at Los Alamos National Laboratory in 1970, and since 1973 has been supported by the U.S. Department of Energy's Office of Renewable Technology and its predecessor agencies. This, however, is a worldwide resource, and the program has attracted increasing international interest. Parallel and complementary programs have been initiated in several other countries, particularly in West Germany, Japan, Great Britain, France, and the Soviet Union.

Since fiscal year 1980, under an International Energy Agency agreement, both West Germany and Japan have participated directly in the U.S. program and have contributed to its financial support and to its technical and scientific staff.

About 7 years ago, we completed the world's first hot dry rock energy system at Fenton Hill, in the mountains west of Los Alamos. We operated it successfully for over a year. It produced heat that could have heated several hundred homes and caused no detectible environmental effect. This was a very successful demonstration and a model for a type of low-temperature geothermal energy system that could be very useful here in the Eastern United States.

To more nearly approach the requirements of a commercial electrical powerplant, we are now developing a larger, hotter system at the same site. We began by drilling two holes at depths around 14,000 feet, where the rock temperature is about 625 °F. These are some of the deepest and hottest geothermal wells that have ever been drilled. We are learning how to connect these holes through the hot rock by fracturing. We have, in fact, already produced several large sets of fractures from the two wells but so far without actually making a connection.

During our most recent fracturing experiment, we injected about 5.6 million gallons of water. This was one of the most ambitious fracturing operations ever attempted. It required a great deal of high-pressure pumping equipment, which was provided by Dowell, an oilfield service company. Dowell pumped water into our injection well at a rate of about 40 barrels per minute and at a pressure of 7,000 pounds per square inch.

We were near the end of the experiment when a lucky accident occurred. A pipe broke next to the well head, and highly pressurized very hot water in the well came to the surface, and jetted across the floor of the drilling rig and the water storage pond beside the rig. Much of the water coming out of the well turned into steam, and the resulting steam cloud frequently rose above the tower of the drilling rig.

An extremely high-rate vent continued for about 3 days and at lower rates for another 4 days. We estimate that the flow out of the well brought heat initially at a rate well over 100-MW thermal. We know from this very rapid vent, from the volume of fluid injected, and from the mapping of source locations of noises generated by the fracturing events, that we have created a very large fracture system. The high rate of fluid return indicates that the fractures are well-connected and that the resistance to fluid flow is extremely low.

The high temperature of the water reaching the wellhead shows that we have created a large amount of fracture surface for heat exchange, and that the heat extraction from the rock is very effective. The relatively rapid return of most of the injected water indicates that the fracture system is well contained within the reservoir rock of very low permeability. When we establish continuous circulation through the reservoir, water losses from it should be extremely small.

All of this indicates that we have created a very large, very hot geothermal reservoir with extremely desirable qualities. When we succeed in connecting it to the other well, it should permit us to produce a lot of heat for a very long period of time. Completing that connection, of course, is our next major task.

When fiscal year 1985 funding is in hand, we propose to redrill the second well into the very large system of fractures produced from the first one. With the two wells connected in this way, we will complete the surface system required to dissipate heat from a large flow of pressurized, very hot water and return it to the injection well. We intend to operate this system for a little more than a year to investigate its thermal and hydraulic behavior and any scaling or corrosion problems. We expect this system to produce on the order of 20-MW thermal to 40-MW thermal, which could heat at least 1,000 homes.

Developing this reservoir and conducting experiments to determine its heat output and useful lifetime will be a major focus of our work for the next 3 years. Completing these tasks could fulfill the IEA agreement with West Germany and Japan. The heat from the reservoir we are creating, however, will utilize only a fraction of the heat that could be produced from the volume of rock between the wells. Therefore, we ultimately would like to connect the two wells through additional fractures at greater depth. We should then operate that system to examine its long-term behavior. We would also like to work with an industrial partner to design and create a hot dry rock system at another site.

We want to make it very clear that we do not intend to go into the electrical power business, although we want to remain available to help those who do and to learn from their results. In the meantime, we are and expect to remain an R&D program, dedicated to developing an almost unlimited, environmentally benign energy system that industry will find useful.

We were the first Hot Dry Rock Geothermal Energy Program in the world and are still the broadest, most ambitious, and most advanced. Necessarily, our experiments are large and expensive. If we were sure of what the results would be, we would not have to do them. And of course, we have had some major surprises.

With regard to equipment, hardware, and techniques, we have learned that many things that work well in the petroleum industry are inadequate for our purposes. With the help of many industrial organizations, we have developed special equipment, instrumentation, and materials ranging from drilling equipment to logging cables and down-hole sensors. Some of these items are now in use by industry and are producing a healthy return on programmatic investment.

We have also had some geologic surprises. Because our field site is close to a major center of recent volcanic activity, our deep holes have entered a true volcanic regime. Our fracturing has permitted carbon dioxide and hydrogen sulfide gases to escape from the reservoir rock. This has played havoc with our drill pipe and well casing. The fracturing behavior of the rock is quite different from that which we observed in shallower holes at the same site. However, we are learning to work with and to overcome these problems.

It is a combination of these problems and the learning process required to manage them that makes it necessary for us to maintain a strong interdisciplinary staff. It is also these factors that will apparently make it necessary in fiscal year 1985 to redrill the lower part of the second well of our new system, which will be quite expensive. That will not be a routine operation, since it will be done directionally and in very hot and very hard rock. We estimate that this operation alone will cost about $2.4 million.

To complete, operate, and learn what we should from our experimental hot dry rock system, it is necessary to maintain our experienced interdisciplinary staff, redrill one of the existing wells, complete the surface system required to circulate water and extract heat from it, and operate the completed system and collect and analyze data from it.

For fiscal year 1985, we estimate the funding requirement at $14.75 million. Of this, $5 million will be contributed by the Governments of West Germany and Japan. The balance, $9.75 million, is what is needed from the U.S. Department of Energy to continue a vigorous, effective program through which we will finally make available a major new energy supply to the United States and to the rest of the world.

I again remind you of the extraordinary advantages of hot dry rock geothermal energy. Our experience to date suggests that it is available nearly everywhere. It is virtually inexhaustible. It does not harm the environment. And it does not produce liquid, gaseous, or solid waste which must be treated or disposed. It poses little risk to plant operators and nearby residents. It works independently of weather conditions, and it utilizes the simplest and least interruptible of supply and transmission systems.

We ask for your continued strong support for this program and thank you for your attention.

[The prepared statement of Dr. Whetten follows:]

U. S. House of Representatives Committee on Science and Technology, Subcommittee on Energy Development and Applications.

March 1, 1984

Testimony of John T. Whetten, Program Manager for the Hot Dry Rock Geothermal Energy Program, Los Alamos National Laboratory.

The Hot Dry Rock Geothermal Energy Program is funded by the U. S. Department of Energy and, under an International Energy Agency Agreement, by the governments of Japan and West Germany.

Dr. John T. Whetten is Deputy Division Leader of The Earth and Space Sciences Division and Program Manager of the Hot Dry Rock Geothermal Energy Program at Los Alamos National Laboratory, Los Alamos, New Mexico. He has been at Los Alamos since 1980.

Before coming to Los Alamos, Dr. Whetten was on the faculty of the University of Washington from 1963 to 1980, serving as Chairman of the Department of Geological Sciences, Associate Dean of the Graduate School, and Professor of Geological Sciences and Oceanography. From 1975-1980 he also was employed as Geologist with the U. S. Geological Survey.

Dr. Whetten received his A.B. from Princeton, his M.S. from California (Berkeley), and his Ph.D. from Princeton. He was awarded a Fulbright post-doctoral fellowship to Australia and New Zealand.

He and his wife, Carol, live in Los Alamos with daughters Krista and Michelle. A third daughter, Andrea, is a freshman at Colorado University.

I appreciate the opportunity to testify before you concerning one of our country's most important energy programs, which has promise of delivering large amounts of energy almost anywhere at competitive prices without sacrificing environmental quality. The objective of the Hot Dry Rock Geothermal Energy Program is to extract natural heat from the earth's crust and bring it to the surface where it can be used to generate electricity, heat homes and greenhouses, process foods and chemicals, and serve many other useful purposes. We have been successful in the following:

- * demonstrating that the resource base is enormous, virtually inexhaustible, and available in all regions of the country;
- * proving the technical feasibility of extracting energy from this resource; and
- * developing tools and instruments necessary to work at the very high temperatures and pressures that are required by this resource.

In short, the funds that have been made available for the Hot Dry Rock Program are providing for the development of a truly viable and realistic alternative energy source. Although we have had to overcome many technical problems--and continue to face some--we have yet to find technical reasons why the hot dry rock concept cannot be made to work. On the contrary, with each technical accomplishment we become more optimistic of the overall potential for this Program. We are excited about it, we know that the energy industry is interested, and we think that everyone should be.

Let me present some background on hot dry rock geothermal energy.

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The Hot Dry Rock Program originated at Los Alamos National Laboratory in 1970, and since 1973 has been supported by the U.S. Department of Energy's Office of Renewable Technology and its predecessor agencies. This, however, is a worldwide energy resource, and the program has attracted increasing international interest. Parallel and complementary programs have been initiated in several other countries, particularly in West Germany, Japan, Great Britain, France, and the Soviet Union. Since 1980, under an International Energy Agency agreement, both West Germany and Japan have participated directly in the U.S. Program, and contributed to its financial support and scientific staff.

About seven years ago, we completed the world's first hot dry rock energy system at Fenton Hill in the mountains west of Los Alamos. We operated it successfully for more than a year. It produced heat that could have heated several hundred homes, and caused no detectable environmental effect. This was a very successful demonstration, and a model for a type of low-temperature geothermal energy system that could be very useful here in the eastern United States.

We constructed that pioneering system by drilling a hole about two miles deep into hot rock, then we pumped water into it until the pressure was sufficient to split the wall of the hole and extend large cracks several hundred feet out, and finally we drilled a second hole down from the surface to intersect those cracks. We then pumped cool water down one hole into the fracture system, where it was heated as it circulated through the cracks, and was then recovered as extremely hot water from the second well. At the surface we extracted its useful heat and returned the cooled fluid through the first hole to recirculate and recover more heat.

To more nearly approach the requirements of a commercial electrical power plant, we are now developing a larger, hotter system at the same site. We began by drilling two holes to depths around 14,000 feet, where the rock temperature is about 625°F. Now we are learning how to connect them through the hot rock by fracturing. We have, in fact, already produced several large sets of fractures from the two wells, but so far without actually making a connection.

During our most recent fracturing experiment we injected about 5.6 million gallons of water into the deeper well, when a pipe broke, permitting highly pressurized water and steam to return to the surface and escape to the atmosphere. The result was spectacular, as you will see in this short film.

(Begin film. Commentary follows.)

This was one of the most ambitious fracturing operations ever attempted. As you see, it required a great amount of high-pressure pumping equipment which was provided by Dowell, an oil-field service company. Dowell pumped water into our injection well at a rate of about 40 barrels a minute and at a pressure of 7000 pounds per square inch.

When the pipe broke next to the wellhead, highly pressurized, very hot water in the well came to the surface and jetted across the floor of the drilling rig and the water-storage pond beside the rig. The crew was able to divert the flow into vent lines that we had provided for just such an occurrence.

Much of the water coming out of the well turned into steam--and the resulting steam cloud frequently rose above the tower of the drilling rig. This high-rate vent continued for about three days and, at lower rates, for another four days.

We estimate that the flow out of the well brought heat initially at a rate well over 100 megawatts thermal--which could, for the period of the vent, have produced about 20 million watts of electricity.

We know from this very rapid vent, the volume of fluid injected, and the mapping of source locations of noises generated by fracturing events, that we have created a very large fracture system. The high rate of fluid return indicates that the fractures are well connected and that the resistance to fluid flow is very low. The high temperature of the water reaching the wellhead shows that we have created a large amount of fracture surface for heat exchange, and that heat extraction from the rock is very effective. And the relatively rapid return of most of the injected water indicates that the fracture system is well contained within reservoir rock of very low permeability. When we establish continuous circulation through the reservoir, water losses from it should be extremely small.

(End of Film)

All of this indicates that we have created a very large, very hot, geothermal reservoir with extremely desirable properties. When we succeed in connecting it to the other well, it should permit us to produce a lot of heat for a very long time. Completing that connection of course is our next major task.

When FY85 funding is in hand, we propose to redrill the second well into the very large system of fractures produced from the first one. With the two wells connected in this way, we will complete the surface system required to dissipate heat from a large flow of pressurized, very hot water and return it to the injection well. We intend to operate this system for a little more than a year to investigate its thermal and hydraulic behavior and any scaling or corrosion problems.

We expect this system to produce 10 to 20 megawatts thermal, which is impressive for a single set of fractures connecting two wells--and could heat at least a thousand homes. However, it is only a fraction of the heat that could be produced from the volume of rock between the wells. Therefore, we ultimately would like to connect the two wells through at least one more set of fractures at greater depth. We should then operate that system for a year or more to examine its long-term behavior and, in particular, to collect the data to predict the useful lifetime of hot dry rock systems. Later, we would like to work with an industrial partner to design and create a hot dry rock system at another site.

We want to make it clear that we do not intend to go into the electrical power business, although we want to remain available to help those who do, and to learn from their results. In the meantime, we are and expect to remain an R&D program, dedicated to developing an almost unlimited, environmentally benign energy system that industry will find useful.

We were the first Hot Dry Rock Geothermal Energy Program in the world, and are still the broadest, most ambitious, and most advanced. Necessarily, our experiments are large--and expensive. If we were sure what their results would be, we wouldn't have to do them. And of course, we have had some major surprises.

With regard to equipment and techniques, we have learned that many things that work well in the petroleum industry are inadequate for service in the hot, high-pressure, aggressive environment of a geothermal well. With the help of many industrial organizations, we have developed special equipment and instrumentation ranging from drilling equipment to logging cables and downhole sensors. Some of these items are now in use by industry and are producing a healthy return on programmatic investments.

We have also had some geologic surprises. Because our field site is close to a major center of recent volcanic activity, our deep holes have entered a true volcanic regime. Our fracturing has permitted carbon dioxide and hydrogen sulfide gases to escape from the reservoir rock. These gases have caused several failures of drill pipe and well casing. And the fracturing behavior of the rock is quite different from that which we observed in shallower holes at the same site. However, we are learning to overcome these problems.

It is a combination of these problems and the learning process required to manage them that makes it necessary for us to maintain a strong, interdisciplinary staff. It is also these factors that will apparently make it necessary in FY85 to redrill the lower part of the second well of our new system, which will be quite expensive. That will not be a routine operation, since it will be done directionally in very hot, very hard rock. We estimate that this operation alone will cost about $2.4 million.

To complete, operate, and learn what we should from our experimental hot dry rock system, it is necessary to:

1. maintain our experienced interdisciplinary staff,
2. redrill one of the existing wells,
3. complete the surface system required to circulate water and extract heat from it, and
4. operate the completed system, and collect and analyze data from it.

For FY85, we estimate the funding requirement at $14.75 million. Of this, $5 million will be contributed by the governments of West Germany and Japan. The balance, $9.75 million, is what is needed from the U.S. Department of Energy to continue a vigorous, effective program in which we will finally make available a major new energy supply to the United States and the rest of the world.

I again remind you of the extraordinary advantages of hot dry rock geothermal energy: it is available nearly everywhere, it is virtually inexhaustible, and it does not harm the environment. It does not produce liquid, gaseous, or solid waste which must be treated or disposed of. It poses little risk to plant operators and nearby residents. It works independently of weather conditions, and it utilizes the simplest and least interruptible supply and transmission systems.

We ask for your continued strong support of this program.

Thank you for your attention. I will welcome your comments and questions.

Mr. **Bateman**. Thank you very much, Dr. Whetten.

I would like, before we turn to questions of members of our panel, to ask unanimous consent that there appear in the record the opening statement of our colleague, Mr. Winn, and likewise a brief opening statement on behalf of myself.

With that, I would ask if Mr. Carney or Mr. Sensenbrenner have questions.

Mr. **Carney**. Yes, Mr. Chairman. Thank you.

Dr. Whetten, your concluding statement is one that would be very exciting to anyone, where you describe the extraordinary advantages of hot dry rock geothermal energy, its availability, the fact that it does not harm the environment, it does not leave any liquid, gaseous, or solid waste which must be treated or disposed of. It sounds to me like we have a panacea here. It just seems too good. Why is it that there are only three nations involved in this endeavor? Why is there not more excitement about it? I am not implying that at your level there is not, but why is there not more support for this type of approach to our energy needs.

Dr. **Whetten**. I think much of the U.S. industrial community and other countries are looking to this program to see the realization of the capability of extracting geothermal energy from hot dry rock. The list of countries that are presented was those countries which, as far as we know, have formal programs to develop hot dry rock geothermal energy. The list of countries which have expressed interest, and we believe to be in the process of developing programs, is indeed very much longer than the list of those countries that have formal programs existing at the present time.

I would indicate that some of those countries are proceeding extremely rapidly to develop their own hot dry rock geothermal programs. For example, in just a few years, the British program at Canbourne School of Mines in Southern England has advanced to the point where its budget is of the same magnitude as ours. We expect that within a year or two, the West German program will be indeed very much larger than ours. These are in countries which have resources which are probably not nearly to the size and extent of the U.S. hot dry rock resource.

I would suggest that interest in this is considerable in international areas.

Mr. **Carney**. I have had an opportunity to go out to the lower part of California, below San Diego and on to the Baja in Mexico, and look at some of the geothermal, not hot dry rock applications that we have out there. The DOE has supported some of the programs, the Government of Mexico in fact has a powerplant that is utilizing geothermal. I quite honestly forget the name of it, but I have been there.

What are the benefits of hot dry rock over those types of applications?

Dr. **Whetten**. The benefits of hot dry rock are that, at least theoretically, it can be utilized anywhere. The more conventional hydrothermal geothermal energy, such as at Cerro Prieto, the area that you visited, are relatively rare because it requires both heat and water to be present in order to extract the energy. In other words, you utilize the natural water which is available in the formation in order to extract the heat.

As you go down in the earth's crust, the heat increases but in a general sense the water decreases; So that it is relatively few areas where you have both heat and water occurring together where you can extract the water.

The hot dry rock method should be available nearly everywhere, because as you go down in depth, the rock gets hotter and it also tends to get less permeable. These are the advantages of the hot dry rock geothermal energy system.

Mr. CARNEY. The expense then to hot dry rock is getting down to a level where the hot dry rock is available? Would that be an assumption I could make?

Dr. WHETTEN. That is indeed true, but that need not be any more expensive than getting to a level where you can produce geothermal energy from hydrothermal systems. It depends upon the thermal gradient.

Mr. CARNEY. That would be more consistent across the country. I see the chairman has the gavel in his hand, so I have to run one quick question by you. I just want to know, why do you have to redrill a well? In the program you were saying the five steps that would be necessary to continue, and one would be to redrill one of the existing wells.

Dr. WHETTEN. Because by pumping cold water down one of the wells, we have made an extremely large reservoir with which we are very pleased because it has the potential for delivering large amounts of energy. We need to make the connection with the second well bore so we can actually circulate this loop. It looks as if we are going to have to redrill the lower part of the well to go into the large reservoir that we have created.

Mr. CARNEY. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. Mr. Duquette, I have a question that Mr. Winn had prepared. This is his question rather than mine, but I do believe it is an important question, particularly as it relates to a project in Kansas.

You spoke in your presentation of the parabolic dish program. A project that Congressman Whittaker and Congressman Winn have been supporting for several years now, the small community project at Osage City, Kansas, recently had bids due to DOE. Representatives of McDonnell Douglas visited Congressman Whittaker on January 31 and stated that your company would not be bidding on that project, even though you have signed a cooperative agreement with United Sterling of Sweden for their solar engines, and that any purchasers of United Sterling engines would first have to acquire a license from McDonnell Douglas.

The question has risen whether or not your exclusive cooperative agreement with United Sterling of Sweden for their sterling engines has possibly eliminated one of the best and most proven engines for the small community solar experiments. What concerns Congressman Winn is that after all the money that the U.S. taxpayers have put into the automotive and solar United Sterling engines for their availability for important solar experiments and future commercialization may be constrained by this agreement.

I doubt that if the large sum of DOE funds that have been spent on McDonnell Douglas to develop heliostats for central receiver technology were meant to have this type of impact on a companion technology. Congressman Winn's question for you, Mr. Duquette, is this: Is there any provision in that cooperative agreement that prohibits United Sterling from participating with other teams who have elected to propose the use of Sterling engines such as in the small community project at Osage City, Kansas? And is there any provision in that cooperative agreement that prohibits United Sterling from selling commercial engines to anyone else in the future?

Mr. DUQUETTE. I do understand the thrust of the question. I guess my understanding of the cooperative agreement between the McDonnell Douglas company and United Sterling had to do with continuing development of a concentrator system that would be conducted in the private sector and, at the end of this development time, would be available then for utilization throughout this country and the world.

With regard specifically to the Osage project, it is my understanding that it was felt that the particular hardware designs that this agreement was addressing would not be ready to be available for that project.

Mr. SENSENBRENNER. I do not think that answers Congressman Winn's question. Is there anything in the cooperative agreement that prohibits United Sterling from participating with other teams who have elected to propose the use of that engine in projects like Osage City or if there is any provision in the agreement that prohibits United Sterling from selling commercial engines to anyone else?

If you do not know the answer to this——

Mr. DUQUETTE. I guess I should say that I really do not know the answer to that. I am not that familiar with that particular project.

Mr. SENSENBRENNER. Could you kindly give a written response to the subcommittee for inclusion in the record, and without objection it will be included in the record when it is received?

Mr. DUQUETTE. I certainly can, congressman.

Mr. SENSENBRENNER. The second question I have is Mr. Harkin's question to Mr. Whetten. Mr. Harkin wants to know why we have not drilled an experimental HDR hole in the Eastern United States, specifically in the States of Maryland and Virginia?

Dr. WHETTEN. At the time of the initial funding of the hot dry rock program at Los Alamos in the early years, from 1973 through 1976 or 1977, with the difficulties in obtaining imported petroleum, there was much more interest on the part of the Department of Energy or its predecessor agency to develop the hot dry rock resource. There were in fact target sites for drilling which were slated for many parts of the United States, including the Eastern parts of the United States as part of the DOE program.

In recent years, the hot dry rock effort has been cut back substantially to include development only of the Fenton Hill site. During the time that we had a larger program, we completed the resource assessment of the entire United States and have at least a first-order approximation of what sites would be attractive and what sites would not be. On the basis of this, we have come to the conclusion that there are in fact many sites in the Eastern United States which would be attractive hot dry rock sites, at least from the point of view of extracting relatively low-grade heat which could be used for space heating, food processing, or other industrial uses.

We feel there is still interest in the Eastern United States in developing these potential hot dry rock sites. We are sure that there will be greater interest when we have completed our work at Fenton Hill. But I think that is the essential reason: It was a program cutback. We would stand ready and available to assist those who would be interested in developing sites for hot dry rock in the Eastern part of the United States

Mr. SENSENBRENNER. Thank you very much.

Are there any further questions of any members of this panel? The gentleman from New York is recognized for 5 minutes.

Mr. CARNEY. We are not going to ask unanimous consent to have a picture painted for this chairman. He is too tough. [Laughter.]

Could you tell me, Dr. Whetten, the total amount of money that you have spent so far on the program?

Dr. WHETTEN. I cannot give you an exact number. It is on the order of $80 million to $90 million so far.

Mr. CARNEY. And this has been in existence since 1970?

Dr. WHETTEN. The idea first germinated in 1970, and the funding first came from AEC in those days.

Mr. CARNEY. The Atomic Energy Commission?

Dr. WHETTEN. The Atomic Energy Commission in 1973.

Mr. CARNEY. Thank you. I would like to make a recommendation that this subcommittee go out there and take a look at it. It seems awfully exciting, Mr. Chairman.

Mr. SENSENBRENNER. Thank you very much to the members of the panel for your testimony today. We appreciate your insight into the renewable energy questions, and we are hopeful we will be able to work something out that is acceptable to all of your individual concerns as well as to the national concern of reducing the deficit.

Our second panel relating to energy conservation consists of Mr. Ralph Knobel, director of the National EES Advisory Board of Fairbury, NE; Robert Lynch, vice president of the Empire State Petroleum Association, in Elmsford, NY; Mortimer Marshall of the National Institute of Building Sciences, in Washington, DC; and Thomas Vonier, American Institute of Architects, in Washington, DC.

Without objection, the prepared statements of each of the witnesses on the second panel will be included in the record, and each of you may say what you would like to say in the order in which you prefer.

Who is first? Mr. Knobel. Please proceed.

## STATEMENT OF RALPH J. KNOBEL, CHAIRMAN, NATIONAL ENERGY EXTENSION SERVICE ADVISORY BOARD

Mr. KNOBEL. Mr. Chairman, members of the subcommittee, my name is Ralph Knobel. I operate a family farm, a cattle and hog feeding operation that also produces feed grains and soybeans just outside of Fairbury, NE.

I am also chairman of the Department of Energy's National Energy Extension Service Advisory Board, and I want to thank you for the kind invitation to appear before you today.

I take this opportunity to present to you the National Energy Extension Service Advisory Board's fifth annual report to the Congress, the Secretary of Energy, and the Director of the Energy Extension Service, as well as to discuss the recommendations contained therein.

At this time, I respectfully request that the fifth annual report and my written testimony be inserted into the record.

I was among the first members appointed to the board when it was originally established back in 1978. Thus, I have been in the position of observing this program as it has evolved over the years.

The National Energy Extension Service Act, which originally established the EES program, also called for the establishment of an advisory board. The act further provided that the members of this board be representative of the various constituencies of the EES Program by requiring that members of State, county, and local governments, State universities, community colleges, community service action agencies, consumers, small businesses, and agriculture be among those appointed to serve.

This makes for a unique and appropriate blending of backgrounds which ensures the production of a report that is free from any single point of view or opinion. Indeed, our recently concluded proceedings reflected a variety of viewpoints on the various issues which we discussed.

This diverse cross section of citizens who make up the membership of the board seemed to have one elemental concern which they all shared, and that is the mounting Federal deficit.

In reviewing the goals, objectives, and current status of the Energy Extension Service Program, we did so in the continuing context of the size of the deficit, and we were determined that whatever recommendations we would make would have to reflect that concern.

As you know, the Energy Extension Service is unique among Federal energy grant programs, as it is designed to provide education, information, and technical assistance to small-scale users in the residential, business, and agricultural sectors.

Initially, the EES program was designed to respond to State needs and Federal policies in an era of oil embargoes, escalating energy costs, and questionable future supplies. While we still have potentially serious threats to our supplies, we also have the difficult matter of the deficit facing our Nation, to which I previously referred.

In its deliberations, the board observed that States and local governments have been and must continue to take an increasing share of the responsibility for determining and supporting energy programs and policies for their particular needs.

As we look around us today, we find many changes have taken place in energy conservation. Not only are citizens, businesses, and communities using energy more efficiently, but a whole industry devoted to energy conservation has come into being.

This leads me to the first of the board's recommendations which I am presenting to you today, the avoidance of duplicating existing services. The board sees the need for more substantive coordination of Federal energy programs within a workable framework. Any duplication of existing services within either the public or private sector must be avoided.

The next recommendation of the board which I would like to bring to your attention is the need for onsite, hands-on technology transfer and the dispersal of information on proven programs. In this, we recommend that the Department of Energy give priority to technology transfer activities in the form of onsite, hands-on demonstrations of new technologies.

This is in contrast to the simple dissemination of brochures, fact sheets, and similar documents which are readily available through the private sector and existing State, local, and Federal Government programs.

Moreover, we feel that a mechanism should be established for the transfer of such proven programs and practices between the States and territories.

The board's attention was also directed toward the matter of landlord-tenant energy conservation incentives, or the apparent lack thereof. In our view, tenants frequently lack the resources to make energy-saving corrections in their domiciles, and landlords simply do not have the necessary incentives. The board recommends that Congress consider appropriate legislation to address this problem, to motivate landlords, particularly those with multiunit holdings, to work with tenants in providing a link between energy consumption and conservation.

Additionally, it is recommended that the emphasis be placed on providing energy outreach programs to tenant recipients of the Low-Income Home Energy Assistance Program and other similar assistance efforts, with the objective of reducing their dependence upon such programs. This would probably require an administrative change in the regulations governing the Low-Income Home Energy Assistance Program as administered by the Department of Health and Human Services.

We now come to the most significant of the board's recommendations, that of the Energy Extension Service Program's viability into the future. This particular recommendation was worded with great care and, lest there be any confusion as a result of paraphrasing the specific language, I will quote directly from the report:

> The board fully recognizes the ongoing nature of the policy conflict between Congress and the current administration regarding the Energy Extension Service funding. The current infusion of oil overcharge funds significantly enhances the program's ability to achieve its intended purpose, and without the funds, the board feels that at a $10 million appropriations level, the EES program is not an effective and viable effort of the Federal Government and would be better left up to the States.
>
> The board strongly recommends that the DOE's proposed Petroleum Overcharge Restitution Fund include EES as a beneficiary because the EES provides the educational link between all of the affected DOE and Health and Human Services State Grant Programs.
>
> Rather than fund only those programs presently included under the Petroleum Overcharge Restitution Fund, including the Low-Income Home Energy Assistance Program, and the Weatherization Assistance Program, and the Institutional Conservation Program, which provide monetary assistance for fuel, weatherization hardware, and school and hospital buildings respectively, consideration should be given to the fact that EES provides a means of effecting implementation of long-term energy savings, practices, and technology transfer. Outreach programs are ill-ad-

vised if not coordinated with educational activities to reinforce energy saving practices necessary for long-term conservation.

In the interim, and until such time as these matters are resolved, the board recommends that the EES program be administered in an aggressive, effective and positive manner that maximizes every possible modern approach in energy outreach management.

Mr. Chairman, members of the subcommittee, this concludes my testimony and presentation of the board's fifth annual report. I will be pleased to answer questions any members may have at the appropriate time.

[The prepared statement of Mr. Knobel follows:]

# STATEMENT OF

RALPH J. KNOBEL

BEFORE THE

HOUSE SCIENCE AND TECHNOLOGY COMMITTEE

ENERGY DEVELOPMENT AND APPLICATIONS SUBCOMMITTEE

CHAIRMAN, NATIONAL ENERGY EXTENSION

SERVICE ADVISORY BOARD

March 1, 1984

Mr. Chairman, Members of the Subcommittee; my name is Ralph Knobel; I operate a cattle, hog and feed-producing farm outside of Fairbury, Nebraska. Also, I am Chairman of the Department of Energy's National Energy Extension Service Advisory Board. I want to thank you for the kind invitation to appear before you today.

I take this opportunity to present to you the National Energy Extension Service Advisory Board's Fifth Annual Report to Congress, the Secretary of Energy and the Director of the Energy Extension Service, as well as to discuss the recommendations contained therein.

I was among the first members appointed to the Board when it was originally established back in 1978. Thus, I have been in the position of observing this program as it has evolved over the years and have had an opportunity to play a key role in the development of each of the four preceding annual reports. As a result, I think it may be worthwhile for me to briefly review the history of the Advisory Board and the evolution of its role in regard to the EES program as evidenced by past reports.

The National Energy Extension Service Act, which originally established the EES program, also provided for the establishment of an Advisory Board. The purpose of that Board was described as, and I quote; "to carry on a continuing review of the operation of the comprehensive Energy Extension Service program and plans for the purpose of evaluating their effectiveness in achieving the objectives of the Act and determining how their operation might be improved and to report at least annually to Congress, the Secretary of Energy and the Director of the Energy Extension Service on the status of the program, including recommendations for the administrative or legislative changes to improve program operation.

The Act further provided that the members of this Board be representative of the various constituencies of the EES program by requiring that members of State, county, and local governments, State universities, community colleges, community service action agencies, consumers, small business and agriculture be among those appointed to serve. This makes for a unique and appropriate blending of backgrounds which insures the production of a report that is free of any single point of view or opinion. Indeed, our recently concluded proceedings reflected a variety of viewpoints on the various issues which we discussed. While this "cross-section of America" membership structure resulted in many long hours of deliberation and discussion, once we reached a consensus on any one issue, we were assured that all possible points of view had been fully expressed and amply considered.

The Board's first report was published in March, 1979 which was during the program's initial ten-State pilot program. Based on the results of an evaluation of that trial effort, the primary recommendation contained in that report called for the expansion of the pilot program to nationwide participation.

The second annual report was published in January of 1981. The main concern at that time was the transition from the pilot program to a national program that had, now, already been accomplished. The Board felt that inadequate resources and management attention was being given to the newly emerging nationwide effort to insure its ultimate success.

The third annual report, published in January, 1982 reflected the significant budgetary changes that were affecting many grant programs at that time. The report realistically recognized that EES must compete with other Federal programs for increasingly scarce funding. The report also acknowledged the possibility of subsuming EES under a block grant approach and was in support of that concept.

The fourth annual report took a somewhat different approach, and undertook a comprehensive review of many of EES's programmatic, administrative and financial aspects. Several recommendations were made which centered on improving general program operations.

Today, I have the distinct pleasure of presenting to you the Board's Fifth Annual Report to Congress, the Secretary of Energy and the Director of the Energy Extension Service. In completing this document, the Board took an approach quite unlike the four previous efforts. For it was our intention from the first of our organizational meetings this year to chart a new and different course which fully recognized the realities of 1984, both in terms of constraints and in terms of possibilities. We began with a program that was designed and implemented in the decade of the seventies, a program that reflected the perceived energy problems of that time period along with the established Federal/State approach to such problems, and gave it a hard, close look. What we found was a basically effective program, that is in need of re-evaluation in light of changing circumstances.

I referred earlier to the diverse cross-section of citizens who make up the membership of the Board. I can assure you that if there is one elemental concern which they all share, it is the mounting federal deficit. In reviewing the goals, objectives and current status of the Energy Extension Service program, we did so in the continuing context of the size of the deficit and we were determined that whatever recommendations we would make would have to reflect that concern.

As you know well, the Energy Extension Service is unique among Federal energy grant programs as it is designed to provide education, information and technical assistance to small-scale users in the residential, business and agricultural sectors. Initially, the EES Program was designed to respond to State needs and Federal policies in an era of oil embargos, escalating energy costs and questionnable future supplies. While we still have potentially serious threats to our supplies, we also have, of equal or greater concern, these Federal deficits which are facing our nation. As a necessary result, States and local governments are taking an increasing share of the responsibility for determining and supporting energy programs and policies for their particular needs. As we look around us today, we find many changes have taken place in energy conservation. Not only are citizens, businesses, and communities using energy more efficiently, but a whole industry devoted to energy conservation has come into being.

This leads me to the first of the Board's recommendations which I am presenting to you today, the avoidance of duplicating existing services. The Board sees the need for more substantive coordination of Federal energy programs within a workable framework. Any duplication of existing services within either the public or private sector must be avoided. Further, the EES program should encourage States to coordinate energy conservation programs with State public utility and other energy commissions or regulatory bodies whenever possible.

The next recommendation of the Board which I would like to bring to your attention is the need for on-site, hands-on technology transfer and the dispersal of information on proven programs. In this, we recommend that the Department of Energy give priority to technology transfer activities in the form of on-site, hands-on demonstrations of new technologies. This is in opposition to the simple dissemination of brochures, fact sheets and similar documents which are readily available through the private sector and existing State, local and federal government programs. Moreover, we feel that a mechanism should be established for the transfer of such proven programs and practices between the States and territories. In supporting this state-of-the-art concept, the Board is striving to make it possible for all States to enjoy the benefits of increased energy efficiency in mutual fashion. We note, however, that the Department is developing a technology transfer program that might accomplish this aim. Until such time as that is established, the Board requests that the EES staff develop and implement an interim effort using the DOE Support Offices to obtain information on the most up-to-date project results. This information will then be made available to the States at their request.

The Board also addressed the matter of grantee evaluation strategy to insure that the most effective performance measuring approach was being used to determine program results. It is our recommendation that individual State programs should utilize actual savings over projected savings where applicable, and the use of utility bills should prove a useful tool for this purpose. Also, the educational programs provided under EES should include a follow-up assessment on the degree of acceptance and implementation of energy conservation measures.

The Board's attention was also directed towards the matter of landlord-tenant energy conservation incentives or, the apparent lack thereof. In our view, tenants frequently lack the resources to make energy saving corrections to their domiciles and landlords do not have the necessary incentives. The Board recommends that Congress consider appropriate legislation to address this problem, to motivate landlords (particularly those with multi-unit holdings) to work with tenants in providing a link between energy consumption and conservation.

Additionally, it is recommended that emphasis be placed on providing energy outreach programs to tenant recipients of the Low-Income Home Energy Assistance Program (LIHEAP) and other similar assistance efforts, with the objective of reducing their dependence on such programs. This would probably require an administrative change in the regulations governing the LIHEAP program as administered by HHS.

We now come to the most significant of the Board's recommendations, that of the Energy Extension Service program's viability in the future. This particular recommendation was worded with great care and, lest there be any confusion as a result of paraphrasing the specific language, I will quote directly from the report:

The Board fully recognizes the ongoing nature of the policy conflict between the Congress and the current Administration regarding the Energy Extension Service funding. The current infusion of oil overcharge funds significantly enhances the program's ability to achieve its intended purpose and without these funds, the board feels that at a $10 million appropriations level, the EES program is not an effective and viable effort of the Federal government and would be better left up to the States.

The Board strongly recommends that the DOE's proposed Petroleum Overcharge Restitution Fund (PORP) include EES as a beneficiary because the EES provides the educational link between all the affected DOE and HHS State Grant Programs. Rather than fund only those programs presently included under PORF (Low-Income Home Energy Assistance Program (LIHEAP), Weatherization Assistance Program (WAP), Institutional Conservation Program (ICP)) which provide one-time monetary assistance for fuel, weatherization hardware, and school and hospital buildings, consideration should be given to the fact that the EES provides a means of effecting implementation of long term energy savings, practices and technology transfer. Outreach programs are ill-advised if not coordinated with educational activities to reinforce energy savings practices necessary for long-term conservation.

In the interim, and until such time as these matters are resolved, the Board recommends that the EES program be administered in an aggressive, effective, and positive manner that maximizes every possible modern approach in energy outreach management.

Mr. Chairman, Members of the Subcommittee; this concludes my testimony and presentation of the Board's Fifth Annual Report. At this point, I would like to respectfully request that it be entered into the record in its totality and I will be pleased to answer any questions which the Members may have for me.

FEBRUARY 1984

# FIFTH ANNUAL REPORT TO CONGRESS AND THE SECRETARY OF ENERGY ON THE NATIONWIDE ENERGY EXTENSION SERVICE PROGRAM

Fifth Report of the
National Energy Extension Service
Advisory Board

U.S. Department of Energy
Assistant Secretary for
Conservation and Renewable Energy
Office of State
and Local Assistance Programs

## NATIONAL ENERGY EXTENSION SERVICE ADVISORY BOARD

February 28, 1984

To: Members of Congress
The Secretary of Energy
The Director of the Energy Extension Service

In accordance with the National Energy Extension Service Act (P. L. 95-39, Title V, Section 509 C), the National Energy Extension Service Advisory Board submits this, its Fifth Annual Report on the status of, and our recommendations for, the Energy Extension Service program.

The Board is submitting this report to the Congress in a timely manner which would allow for it to be included in the present budget deliberations. While there are several important recommendations contained herein for your consideration, we would like to highlight that a general cohesive theme recurred throughout our discussions. Our overriding concerns have been the aspects of program effectiveness and the need for long-term return rather than short-term, short-lived benefits.

Having submitted this, our annual report, the Board would like to maintain and pursue a continuing oversight relationship with the EES. We hope that a greater effort on our part will be rewarded wth the establishment of better cooperation in our joint efforts to implement and manage effective and viable energy conservation programs.

As always, members of the Board are prepared to meet with Congress, the Secretary of Energy, and the Director of the Energy Extension Service to discuss the report's contents and recommendations.

Sincerely Yours,

Ralph Knobel

Ralph J. Knobel
Chairman

Glenna Cornelius

Glenna Cornelius
Vice Chairman

## OPENING STATEMENT

This the Fifth Annual Report of the National Energy Extension Service Advisory Board to the Congress and the Secretary of Energy. The Board is charged by the National Energy Extension Service Act of 1977 (P.L. 95-39) with carrying on a continuing review of the Energy Extension Service program and reporting on at least an annual basis as to its status and any recommendations for improvement.

In developing our approach to this year's report, we have concentrated on those matters that appear to be critical issues facing the EES program at the current time.

These issues include:

1. Program Viability;
2. Landlord-tenant Energy Conservation Incentives;
3. Grantee Evaluation Strategy;
4. Hands-on Technology Transfer
5. Transfer of Proven Programs; and
6. Avoiding the Duplication of Services.

The Board, in conformance with its legislative mandate, would like to maintain and pursue a continuing oversight relationship with the EES program. Such a continuing relationship would assist the Board to track its recommendations in terms of response actions taken, identify new areas for study and analysis, and permit advance preparation for development of its Sixth Annual Report in the coming year.

The Board stands ready to cooperate in any fashion, through the provision of additional information as needed by the Congress or the Secretary of Energy.

## HISTORY AND BUDGET

The national Energy Extension Service (EES) is a Federal/State partnership designed to give personalized information and technical assistance to small-scale energy users on energy conservation and the use of renewable resources. Fifty-seven States and territories receive grants to work personally with families, owners of small companies, and local government officials to help them take practical steps to save energy.

The EES was authorized by the National Energy Extension Service Act of 1977. Originally, the program was initiated as a nineteen-month pilot program in the following ten states: Alabama, Connecticut, Michigan, New Mexico, Pennsylvania, Tennessee, Texas, Washington, Wisconsin, and Wyoming. In August 1979, based on an evaluation of the pilot program, Congress approved expansion of the effort nationwide.

With national implementation of the Program, Congress increased funding with appropriations of $25 million in FY 1980 and $22 million in FY 1981. In FY 1982, President Reagan proposed discontinuance of the Program, but Congress disagreed and funded the Program at a level of $9.6 million. In FY 1983 and FY 1984, President Reagan again proposed zero funding for the program but Congress appropriated $10 million for each year, respectively. DOE has taken the position that the Program should be discontinued. DOE has also taken the position that, if Congress continues to appropriate funds and mandate program continuance, the program will be managed as effectively and efficiently as possible.

Services such as energy audits and self-help workshops have been tailored to the needs of homeowners, small businesses, local governments, and other public institutions. States are given broad flexibility in service design so that particular local needs can be met through the program and so that EES activities can be used to supplement or complement other conservation and renewable resource programs.

The Department of Energy provides EES grant funds to State Energy Offices or other State entities designated by the Governor to manage the program. States distribute these funds to their individual projects according to a plan which they prepare and submit to DOE for approval.

Section 509 of the National Energy Extension Service Act created the National Energy Extension Service Advisory Board. The Act directs the Board to:

- Carry on a continuing review of the operation of the comprehensive Energy Extension Service program developed under Section 504 and the various State plans approved under Sections 505 and 506, for the purpose of evaluating their effectiveness in achieving the objectives of the National Energy Extension Service Act and determining how their operation might be improved in furtherance of such objectives.

- Report at least annually to Congress, the Secretary of Energy, and the Director of the Energy Extension Service on the status of the program, including recommendations for administrative or legislative changes to improve its operations.

The National Energy Extension Service Act requires that the funds appropriated shall be allocated in accordance with the following formula: (1) one half divided equally among the States and territories and (2) one half divided among the States and territories in proportion to their respective populations based on the most recent decennial census.

## Petroleum Violation Escrow (PVE)

Under the FY83 Appropriation Act Congress approved the disbursement of $200 million from the oil violation escrow account to the States to fund any of the following programs: Weatherization Assistance Program (WAP), State Energy Conservation Program (SECP), Institutional Conservation Program (ICP), Energy Extension Service (EES), and the Low-Income Home Energy Assistance Program (LIHEAP). This provision of the Act is known as the Warner Amendment (Sec. 155), named for its sponsor, Senator John Warner

## Budget History

There have been various levels of funding for EES. The following appropriations and allocations from PVE have been made for the EES since its inception.

| Fiscal Year | | Appropriated $(Million) | PVE $(Million) |
|---|---|---|---|
| 1977 | | $ 7.5 | 0 |
| 1978 | | 7.5 | 0 |
| 1979 | | 15.0 | 0 |
| 1980 | | 25.0 | 0 |
| 1981 | | 22.0 | 0 |
| 1982 | | 9.6 | 0 |
| 1983 | | 10.0 | 0 |
| 1984 | | 10.0 | 12.2* |
| | Total | $ 106.6 | $12.2 |

## RECOMMENDATIONS

Based on the foregoing, and, in careful consideration of all information made available to the Board, the following specific recommendations of the National Energy Extension Service Advisory Board are made:

### 1. Program Viability

The Board fully recognizes the ongoing nature of the policy conflict between the Congress and the current Administration regarding the Energy Extension Service funding. The current infusion of oil overcharge funds significantly enhances the program's ability to achieve its intended purpose and without these funds, the Board feels that at a $10 million appropriations level, the EES program is not an effective and viable effort of the Federal government and would be better left up to the States.

*Approximately 50 percent of the States elected to put a total of $12.2 million into EES under provision of the Warner Amendment. This amounted to 6 percent of the total Warner Amendment Funds.

The Board strongly recommends that the DOE's proposed Petroleum Overcharge Restitution Fund (PORF) include EES as a beneficiary because the EES provides the educational link between all the affected DOE and Department of Health and Human Services (HHS) State Grant Programs. Rather than fund only those programs presently included under PORF (LIHEAP, WAP, ICP) which provide one-time monetary assistance for fuel, weatherization hardware, and school and hospital buildings, consideration should be given to the fact that the EES provides a means of effecting implementation of long term energy savings, practices, and technology transfer. Outreach programs are ill-advised if not coordinated with educational activities to reinforce energy savings practices necessary for long-term conservation.

In the interim, and until such time as these matters are resolved, the Board recommends that the EES program be administered in an aggressive, effective, and positive manner that maximizes every possible modern approach in energy outreach management.

## 2. Landlord-tenant Energy Conservation Incentives

Low-income energy users, many of whom are tenants, are not adequately implementing energy conservation measures. There is a lack of understanding as to the correlation between effective conservation and energy costs. In many cases, the tenants have inadequate resources and the landlords do not have the incentives to make energy savings corrections.

The Board recommends that Congress consider legislation to address this problem. An incentive program is necessary to motivate landlords, particularly with multi-unit holdings, to work with tenants in providing a link between energy consumption and energy conservation.

Additionally, it is recommended that emphasis be placed on providing energy outreach programs to tenant recipients of the Low-Income Home Energy Assistance Program (LIHEAP) and other similar assistance efforts, with the objective of reducing their dependence on such programs. This would probably require an administrative change in the regulations governing the LIHEAP program as administered by HHS.

## 3. Grantee Evaluation Strategy

All grantees and subgrantees should describe in their annual plan or proposal the evaluation strategy to be used to measure performance during and upon completion of the program to serve as a criteria in determining the direction of future activities.

Individual State programs must include a determination of end results, using actual savings versus projected savings where applicable, to answer the question of program effectiveness in saving energy. For example, when at all possible, utility bills should be used to monitor energy savings. In addition, the educational programs provided under EES should include a follow-up assessment on the degree of acceptance and implementation of Energy Conservation measures.

It is not the intention of the Board to require additional allocations of funds for evaluation efforts. Rather, evaluation should be made an integral part of program planning and implementation.

### 4. Hands-on Technology Transfer

The Board recognizes the unique value of technology transfer initiatives in assuring that States have access to the most up-to-date, useful, and proven conservation and renewable energy technologies. It is, therefore, the position of this Board that the Department of Energy, with the support of the Congress, give priority to technology transfer activities in the form of on-site, hands-on demonstrations of new technologies, as opposed to the simple dissemination of the written word in the form of brochures, fact sheets, and similar types of documents. These latter examples of information dissemination efforts are readily available through the private sector and currently existing State, local, and Federal government programs.

### 5. Transfer of Proven Programs

The Board recommends the establishment of a mechanism for transfer of proven programs and practices between the States and territories. This should result in the transfer of proven energy conservation techniques and technologies which demonstrate energy savings. The Board recognizes that many good local programs have been developed and implemented which effectively address EES objectives. Conversely, the Board sees this effort as a means of avoiding the replication of ineffective programs and practices.

In supporting a state-of-the-art "clearinghouse" concept, the Board is striving to make it possible for all States to enjoy the benefits of increased energy efficiency in mutual fashion. Until such time as DOE establishes its proposed technology transfer program, the Board recommends that the EES staff develop and implement an interim effort. One cost-effective method of accomplishing this would be the regular dissemination of EES projects among the States, using the DOE Support Offices to obtain the most up-to-date project results. It should be left to the EES staff to design the most appropriate cost-effective mechanism for this purpose.

### 6. Avoiding the Duplication of Services

There must be substantive coordination of Federal energy conservation programs within a workable coordinating mechanism. Any duplication of services within the public and private sectors must be avoided. Further, the EES program should encourage States to coordinate energy conservation programs with State public utility/regulatory and other energy commissions and with the private sector.

## CONCLUSION

This concludes the Fifth Annual Report to the Congress, the Secretary of Energy and the Director the Energy Extension Service program. The Board has previously stated its willingness to provide additional information as might be requested and stands ready to do so. In like manner, it is fully anticipated that the Congress will give close scrutiny and careful consideration to the Boards' several recommendations.

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Mr. LEWIS [acting chairman]. Thank you, Mr. Knobel.

I think we will just continue on and then have questions when the panel completes.

Mr. Lynch, why don't you proceed?

## STATEMENT OF ROBERT D. LYNCH, EXECUTIVE VICE PRESIDENT, EMPIRE STATE PETROLEUM ASSOCIATION

Mr. LYNCH. My name is Robert D. Lynch. I am executive vice president of the Empire State Petroleum Association, and my comments today also reflect the opinions of some 6,000 oil fuel marketer members of the National Oil Jobbers Council who provide fuels, heating equipment, and service to more than 14 million American homes.

We appreciate this opportunity to present our views on the fiscal year 1985 authorization for DOE's energy research and development programs.

Our first concerns about DOE's building energy research agenda occurred about a year ago, after participating in a DOE seminar to examine the current status and appropriate future plans for Government space conditioning equipment research and development.

Since that time, DOE, with the encouragement of some industry representatives, appeared to have adopted a policy of withdrawing from many space conditioning, equipment development and commercialization areas and limiting their interest to funding long-term, high-risk ventures.

It is now becoming clear that the new DOE policy direction is being pursued in the fiscal year 1985 authorization requests and threatens to deny hard-pressed oil heat users vital benefits of Government-supported energy research.

In comparison, it should be noted that DOE's recommendations and directions maintain a strong Federal R&D agenda that meshes well with the existing gas and electric utility infrastructure. To be sure, we recognize that it is appropriate to interface with the utilities and their extensive research organizations.

However, DOE's proposed structural arrangement totally ignores essential differences in addressing the oil heat industry and the needs of millions of energy consumers who have borne some of the highest fuel costs since 1973.

Oil heat consumers make up 20 percent of American homes and should not be deprived of the potential benefits of the present funding activities of your committee.

For many years, the gas and electric utilities have developed comprehensive research facilities, such as the American Gas Association Laboratory, the Electric Power Research Institute, the Gas Research Institute, and the Institute of Gas Technology, which provide applied research and equipment commercialization while retaining proprietary rights.

This practical research development is included in the utilities' rate base, as authorized under monopoly 11 franchises granted by Federal and State authorities. What the utilities want, and are getting in the proposed recommendations, is to have DOE supplement the utilities' proprietary commercialization research with Government-sponsored long-term, expensive, high-risk basic research.

Whatever the merits, such a strategy by DOE does not address the oil consumers' research and development needs.

By contrast, local oil heat marketers have no exclusive sales territories and no governmental approval for means to assess research and development surcharges. Major oil companies, which produce and refine oil products, no longer accept responsibility for any research and development activities in behalf of the equipment manufacturers or end users, whether it is automobiles, airplanes, or space conditioning.

Most manufacturers of oil heat equipment also make gas and/or electric appliances. With a relatively smaller sales potential in oil, it is understandable the equipment manufacturers committed their limited resources where the Government and the utilities are focusing their research dollars.

Considering DOE's unique overview and responsibility for all forms of energy, it is disappointing that there has never been any effort by DOE to develop any coordinated, cooperative oil heat industry equipment research and development program since the 1973 oil embargo.

It is equally disconcerting to realize that 10 years ago, 95 percent of the Federal budget for energy research was devoted to fuels and power generation, and less than 2 percent to the combustion process and improving end-use efficiency. Despite fuel resources becoming more scarce and more costly, the same Government research and development imbalance exists today.

The simple fact is that the only Government or industry research and development activity for the benefit of oil heat users in the last 12 years is the one initiated by the House Science and Technology Committee. The authorization, sponsored by former Congressman John Wydler with strong bipartisan support and approved by the Congress, directed modest funds to Brookhaven National Laboratory to investigate and recommend ways to overcome the institutional barriers to the development and marketing of more efficient oil heating equipment.

That program at Brookhaven, authorized by the House Science and Technology Committee, was the single most important factor in the public acceptance of high efficiency oil equipment. Tens of thousands of oil heat users took advantage of the potential savings and were able to reduce their fuel costs, at the same time enabling the Nation to reduce its imports in the critical period before the strategic petroleum reserve was in place.

One measure of the success of the program is revealed in data compiled by New York State documenting that from 1979 to 1982 residential oil heat conservation amounted to 24 percent, compared to 8 percent for gas utility customers.

Despite its relatively short duration, the applied research program at Brookhaven National Laboratories had a synergistic effect on oil heat industry equipment development, on technology transfer and consumer education.

It is a credit that a high-tech nuclear research facility could successfully administer such a practical applied research effort. Part of the motivation undoubtedly stems from the fact that most Brookhaven lab personnel live in oil-heated homes with very expensive electricity as their only alternative energy option.

We are told that with the difficulties facing the nuclear industry, the Nation will still be dependent on conventional fuels, including oil, well after the turn of the century. Therefore, it seems not only equitable but prudent as well to assure that the modest oil heat research and development effort in behalf of 20 percent of the Nation's homeowners is strengthened and certainly not terminated.

We urge the House Science and Technology Committee to address this issue in consideration of DOE's fiscal year 1985 budget request for building energy research.

I will be pleased to answer any questions from the committee members.

[The prepared statement of Mr. Lynch follows:]

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We urge the House Science and Technology Committee to address this issue on consideration of the DOE fiscal year 1985 budget request for building energy research.

### BACKGROUND INFORMATION ON ROBERT D. LYNCH

Mr. Lynch is executive vice president of the Empire State Petroleum Association [ESPA], serving 450 petroleum marketers in the State of New York. ESPA is one of the constituent member states of the National Oil Jobbers Council.

Mr. Lynch is a graduate of Georgetown University, majoring in economics. He has spent his entire business career in the energy industry.

He served as executive vice president of National Oil Fuel Institute, and in that capacity was responsible for the oil heat industry's equipment research and development program.

Mr. Lynch is a member of the American Petroleum Institute, and has been a member of the National Petroleum Council which advises the Secretary of Energy on petroleum supply and security matters. He has served on three different Presidential Energy Committees.

He was the oil industry representative on the American Society of Heating, Refrigeration, Air-Conditioning Engineers Panel 90-12 covering the issue of fuel resource efficiencies; and was the Secretary of Underwriter Laboratories Oil Heat Advisory Committee. Mr. Lynch also serves on several fire safety committees at the National Fire Protection Association, and other technical standard writing bodies.

Mr. LEWIS. Thank you, Mr. Lynch.

We will now hear from Mr. Marshall, and I would like to point out for the record that all of your written statements will be made a permanent part of the record of the committee.

## STATEMENT OF MORTIMER M. MARSHALL, TREASURER AND DIRECTOR, NATIONAL INSTITUTE OF BUILDING SCIENCES

Mr. MARSHALL. Thank you, Mr. Chairman. I would like to brief my statement on that basis.

Mr. Chairman, members of the committee, my name is Mortimer M. Marshall, FAIA, treasurer and director of the National Institute of Building Sciences. I am presently the owner and senior partner in the architectural firm of Marshall Group, Limited. Formerly, I directed the Office of Design and Construction Standards for the U.S. Department of Defense.

I am pleased to appear before you today to provide on behalf of NIBS commentary on the Department of Energy's Building Energy Research and Development Office fiscal year 1985 budget request.

My remarks shall be confined to the activities of the BERD Program as it is this aspect of the total DOE budget that most directly impacts the way we design for and use energy in our Nation's building stock.

The authorizing statute for NIBS set forth the requirement that NIBS consult with agencies of Federal, State, and local government on matters relating to building codes, standards, and new technology. In accomplishing this, the institute is required to draw on the technical and scientific expertise of the public and private sector through its Consultative Council.

Currently over 700 major building product manufacturers, trade and professional associations, construction companies, labor organizations, research laboratories, academic institutions, and consumer members of the Consultative Council provide this expertise.

This unique mechanism is in place and can be quite useful for the development of authoritative commentary on the research needs of the building community. It is in this context that the National Institute of Building Sciences is interested in and concerned for the BERD Program.

First, I would like to acknowledge the improved recognition of the current administration of the important role that energy conservation in buildings can play in helping us to achieve greater economic stability and better security as a Nation. Strengthened support for the Building Energy Research and Development Program has been a noticeable shift in policy of the administration and has led to a greater reliance on DOE as a source of energy conservation information.

With respect to DOE's role in sponsoring and managing research projects, we believe there are several points which need to be made: One, DOE should be aggressively promoting basic research activities which will lead to new knowledge in materials science. DOE should not aspire to be the leading research and information source with respect to data and technical findings in building energy conservation.

DOE should not duplicate the activities of private research laboratories or industry in attempting to develop new products or technology to reduce energy consumption in buildings.

DOE needs a long-range plan with itemized research activities and objectives stated clearly and adhered to by agency officials.

And, finally, DOE needs adequate budgetary resources to assure that research objectives are met in a timely manner and that continuity of effort is maintained.

NIBS was an invited participant at three of the four building energy conservation workshops organized and hosted by the House Science and Technology Committee beginning in January 1983. In each case, we participated in cooperation with others in the identification of generic research activities for whole buildings and building equipment.

Several conclusions were reached during these sessions with regard to the interfacing of public and private energy conservation research and development activities. In our opinion, the most important of these conclusions were that: 19 DOE's role in supporting research on energy use in buildings should remain limited to basic research activities primarily involving material sciences.

The BERD Program needs to be stabilized at a level of funding which will permit continuity of program effort and retention of key departmental personnel.

And, three, a mechanism is needed to assure meaningful interaction and exchange of research-related information between the department, other Federal agencies, and the private sector.

The building industry is highly fragmented and characterized by thousands of small business concerns, many competing with one another with extremely limited resources. The larger companies in the building product manufacturing and supply field have well-financed R&D activities to support a particular product line, but much of this information is considered proprietary and is withheld from competing corporate interests.

We are aware of a major manufacturing interest with R&D programs in the energy conservation area, and several of these corporations provide summaries of their investment strategies with itemized budget categories for R&D in their published annual reports. However, the level of detail and descriptive literature on corporate R&D in energy is minimal at best. Publicly financed laboratories and research activities are better able to list and describe relevant research activities.

One of the conclusions reached during the Airlie workshop on building energy equipment was that DOE and other publicly funded R&D institutions should not be involved with product development, testing, and demonstrations. These are areas quite well managed by private companies with a vested interest in marketing a particular technology.

The converse of this conclusion is the fact that basic materials research serves many industries and can be utilized by many segments of the private sector to stimulate developmental work on new products, components and systems. The DOE role in these efforts must be quite strong.

The net result of substantial basic materials research investments in R&D would be dollar savings in the private sector among those corporations involved in basic research and a shift of these private resources into more areas more likely to support product development and testing that adequately responds to basic research results. If tax dollars are to be used for the broadest public good, they should be invested so as to produce and findings that can be used by a broad audience.

It should be noted that the administration has requested greater funding for the Building Energy Research and Development each year since the transition, clearly indicating an emerging consensus on the level of support needed for the Building Energy Research Development.

The fiscal year 1985 request indicates that the funds will be used to support building systems, research in such areas as wall and roof systems, indoor air quality, infiltration and ventilation, lighting and retrofit of existing buildings. Some work in the area of technological problems and institutional barriers that impede the use of integrated community energy systems is also intended.

However, the industry seems to think that basic research or materials research, not systems research, is of primary importance. Therefore, it would seem that a reordering of some BERD priorities in response to the recommendations from the recent workshops would be appropriate.

Turning to the area of technology transfer, we agree that greater emphasis is needed on enhancing the existing mechanisms for exchange of technical information. This is one of the most vital services that Government can provide for private industry. The $200,000 approved in fiscal year 1984 was only the beginning, and we note with interest the fiscal year 1985 request for $4.5 million.

We would only caution the committee that the view held by some that technology transfer is merely the packaging of data derived be DOE-sponsored research efforts and the dissemination of published reports among design professionals is not the case. As an architect, I think that to presume technical data on DOE-sponsored materials and systems research is going to be used by design professionals as food for creative thought on the actual design of a building which must respond to a client's needs is not realistic.

The actual design process is not characterized by lofty thinkers culling over reams of papers summarizing research results in search of inspiration. It is more often the case where the architect or engineer is evaluating commercially available building products and systems from manufacturer's literature and product specifications.

The creation of a building is very much an arduous process of selecting a combination of materials and products which will perform in ways that will respond to the designer's interpretation of a client's problem.

The point here is that technology transfer, if it is to be useful, must enhance the ability of researchers, product manufacturers, academicians, scientists, code authorities, builders, designers, and others in the building community to openly exchange information of a technical nature.

Some of the most remarkable advances in building design and construction were really advances in materials sciences developed for other industries that were recognized as having broad applications in buildings.

As we begin to plan for comprehensive technology transfer, it behooves us to recognize how earlier technologies evolved and to support a hastening of communication between various industries that will lead to more rapid product or system development.

The meetings hosted by the House Science and Technology Committee over the past year have been useful in attempting to focus interested sectors of the building community on the programs and activities of the Department of Energy. Many private sector groups now have a better understanding of what DOE's role in this area should be and can be.

Unfortunately, not enough time was set aside during the workshops to provide similar views on private sector research initiatives. An exchange of views on private sector R&D initiatives would be valuable to help the DOE frame its R&D priorities.

If this begins to sound like a suggestion that these workshops be continued and better structured, that is just what is intended. NIBS has offered to assist DOE and the committee with the administrative task of continuing the 3-day discussions on a semiannual basis.

We believe the DOE BERD program has suffered from the following: Lack of consistency in budget authority to allow fulfillment of long-range goals and objectives; lack of staff resources and a continual eroding of knowledgeable staff manpower; lack of ability to plan integrated research efforts relative to private sector R&D programs as no mechanism is being used to facilitate this communication; internal management problems that make it difficult for responsible contractors and consultants to devote significant amounts of time and energy to DOE program directions.

The DOE 5-year plan that was developed several years ago and undergoes an annual revision and update is in serious question. We believe the relationship of the plan to private sector R&D activities needs to be better coordinated, and we sense a lack of commitment to the plan on the part of agency officials.

A new look at the plan would be appropriate, taking into account information from private sector R&D entities, with timetables and cost estimates that would facilitate better decisions on BERD resource allocations.

With regard to specific programmatic areas within BERD that should be supported or enhanced, we believe there is justification for stronger DOE involvement in "whole buildings" research, under the assumption that most large buildings are uniquely designed and unique unto themselves; that every existing building is a laboratory containing potentially useful data and information about the performance of materials, systems, and equipment used therein. Such data can be drawn from buildings and analyzed for its impact on future decisionmaking.

In the area of equipment research, we note that many of the areas recommended for DOE involvement during the Airlie workshop are already programmed activities within the BERD Building Equipment Division. Based upon earlier NIBS statements before this committee, we would agree that fewer funds should be made available in the appliance standards area and that greater emphasis is needed in technology and consumer products.

I would like to take this opportunity to again direct the committee's attention to the NIBS authorizing legislation, to the fact that the Congress intended the institute to become an authoritative source of information on building codes, standards, and new technology.

In 1983, based upon a recommendation contained in the March 1982 report entitled, "National Program Plan for the Thermal Performance of Building Envelope Systems and Materials," the Building Thermal Envelope Coordinating Council was established under the aegis of the National Institute of Building Sciences as a voluntary organization composed of representatives of both the public and private sectors. The mission of BTECC includes the stimulation and coordination of research, development, and verification of technology as it relates to the thermal performance of housing and building envelopes.

It is our desire to see this committee and the Department of Energy play active roles in seeing that some financial support from Federal sources be provided to match contributions and membership dues from the private sector. Thus, the Council will become a viable partnership between Government and industry who share the common goal of expanding our knowledge in building science.

Mr. Chairman and members of the committee, thank you for inviting our views on this important matter, and please contact the staff of the National Institute of Building Sciences if additional information is needed.

With me today is Mr. Steven L. Biegel, AIA program director at NIBS. We will be happy to respond to any questions you have at this time.

Thank you.

[The prepared statement of Mr. Marshall follows:]

A Statement By

Mortimer M. Marshall, FAIA

on behalf of

The National Institute of Building Sciences

on

FY 1985 Authorization for the Department of Energy's
Solar and Conservation Research and Development Program

before

The Subcommittee on Energy Development and Applications
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C.

March 1, 1984

National Institute of
BUILDING SCIENCES

Mr. Chairman, members of the Subcommittee, my name is Mortimer M. Marshall, FAIA, Treasurer and a Director of the National Institute of Building Sciences (NIBS). I am presently the owner and senior partner in the architectural firm of the Marshall Group, Ltd. Formerly, I directed the Office of Design and Construction Standards for the U.S. Department of Defense. I appear before you today to provide commentary on the FY '85 budget request for the Department of Energy's Building Energy Research & Development (BERD) Office. My remarks shall be confined to the activities of the BERD program as it is this aspect of the total DOE budget that most directly impacts the way we design for and use energy in our nation's building stock.

It is important for the Subcommittee to recognize that NIBS was authorized by the Congress and that the NIBS' Board of Directors were initially appointed by the President of the United States, with the advice and consent of the Senate. The authorizing statute for NIBS, Section 809 of P.L. 93-383, set forth the requirement that NIBS consult with agencies of Federal, state, and local government on matters relating to building codes, standards, and new technology. In addition, the Institute is required to draw expertise on technical and scientific matters from public and private sector sources through what is known as the Consultative Council. Currently, over 700 major building product manufacturers, trade and professional associations, construction companies, labor organizations, research laboratories, academic institutions, and consumers comprise the membership of the NIBS Consultative Council. This unique mechanism is in place and can be quite useful for the development of authoritative commentary on the research needs of the building community. It is in this context that the National Institute of Building

Sciences is interested in and concerned for the BERD program.

First, I would like to acknowledge the fact that much progress has been made on the part of the current administration in recognizing the important role that energy conservation in buildings can play in helping us to achieve greater economic stability and better security as a nation. In three years the administration's budget requests for the Conservation and Renewable Energy segment of DOE have increased dramatically. Strengthened support for the Building Energy Research & Development (BERD) program has been a noticeable shift in policy for the Administration and has led to greater reliance on DOE as a source of energy conservation information.

With respect to DOE's role in sponsoring and managing research projects which attempt to expand the knowledge base of energy use characteristics in buildings, there are several points which need to be made:

1) DOE should be aggressively promoting basic research activities which will lead to new knowledge in materials science;
2) DOE should not aspire to be the leading research and information source with respect to data and technical findings in building energy conservation;
3) DOE should not duplicate the activities of private research laboratories or industry in attempting to develop new products or technology to reduce energy consumption in buildings;
4) DOE needs a long range plan with itemized research activities and objectives, stated clearly, and adhered to by agency officials; and
5) DOE needs adequate budgetary resources to assure that research

objectives are met in a timely manner and that continuity of effort is maintained.

NIBS was an invited participant at three of the four building energy conservation workshops organized and hosted by the House Science & Technology Committee beginning in January of 1983. Specifically, we provided input and advice during the Carmel session, the Airlie session, and the recent Hunt Valley meeting north of Baltimore. In each case we contributed our expertise, in cooperation with others, toward the identification of generic research activities for whole buildings and building equipment. Several conclusions were reached during these sessions with regard to the interfacing of public and private energy conservation research and development activities. Most important among these conclusions, in our opinion, were the following:

1. DOE's role in supporting research on energy use in buildings should remain limited to basic research activities primarily involving material sciences;
2. the BERD program needs to be stabilized at a level of funding which would permit continuity of program effort and retention of key departmental personnel;
3. a mechanism is needed to assure meaningful interaction and exchange of research related information between the department, other federal agencies, and the private sector.

This Subcommittee is well aware that the building industry is highly fragmented and characterized by thousands of small business concerns, many competing with one another, with extremely limited capital resources. The larger companies in the building product manufacturing and supply field have well-financed R&D activities to support a particular product line, but much of this information is considered proprietary and is withheld from competing corporate interests. The National Institute of Building Sciences is very much aware of the major manufacturing interests with R&D programs in the energy conservation area. Several of these corporations will provide summaries of their investment strategies with itemized budget categories for R&D as part of their published annual reports made available to stockholders and others. However, the level of detail in descriptive literature on corporate R&D in energy is minimal at best. Publicly financed laboratories and research institutions are better able to list and describe relevant research activities.

One of the conclusions reached during the Airlie Workshop on Building Energy Equipment was that DOE and other publicly funded R&D institutions should not be involved with product development, testing, and demonstration. These are areas quite well managed by private companies with a vested interest in marketing a particular technology.

The converse of this conclusion is the fact that basic materials research serves many industries and can be utilized by many segments of the private sector to stimulate developmental work on new products, components and systems. The DOE role in these efforts should be quite strong. The net result of substantial basic materials research investments in R&D would be dollar savings in the private sector among those corporations involved in basic research and a shift of these private resources into areas more likely to support product development and testing. If tax dollars are to be used for the broadest public good, they should be invested so as to produce data and findings that can be used by a broad audience.

The Buildings and Community Systems division within the Conservation

Research and Development program is shown to receive $35.3 million in FY 1985, according to DOE's published budget highlights. This represents a reduction of $2.1 million over FY 1984, $7.5 million over FY 1982, and $49.7 million over 1980. On the other hand, the administration has requested greater funding for BERD each year since the transition. Clearly, a consensus on the level of support needed for BERD is emerging.

The published description which corresponds to the Buildings and Community Systems request indicates that the $35.3 million will be used to support building systems research in such areas as wall and roof systems, indoor air quality, infiltration and ventilation, lighting, and retrofit of existing buildings. Some work in the area of technological problems and institutional barriers that impede the use of "integrated community energy systems" is also intended. As stated earlier, the industry seems to think that basic research or materials research, not systems research, is of primary importance. It would seem that a re-ordering of some BERD priorities in response to the recommendations from the recent workshops would be appropriate.

Turning to the area of Technology Transfer, we agree that greater emphasis is needed on enhancing the existing mechanisms for exchange of technical information. This is one of the most vital services that government can provide for private industry. The $200,000 approved in the FY 1984 budget was only the beginning and we note with interest the FY 1985 request of $4.5 million. We would only caution the Subcommittee that the view, held by some, that Technology Transfer is merely the packaging of data derived by DOE sponsored research efforts and the dissemination of published reports among design professionals (i.e. architects and engineers is not the case). As an architect myself I can tell you that to presume technical data on DOE sponsored materials and systems research is going to be used by design professionals as food for creative thought on the actual design of a building which must respond to a client's needs is not realistic. The actual design process in an architectural office is not characterized by lofty thinkers culling over reams of papers summarizing research results in search of inspiration. It is more often the case where the architect or engineer is evaluating commercially available building products and systems from manufacturer's literature and product specifications. The creation of a building is very much an arduous process of selecting a combination of materials and products which will perform in ways that will respond to the designer's interpretation of a client's problem.

The point here is that a Technology Transfer program, if it is to be useful, must enhance the ability of researchers, product manufacturers, academicians, scientists, code authorities, builders, and designers to openly exchange information of a technical nature. Some of the most remarkable advances in building design and construction were really advances in material sciences developed for the automotive and aeronautic industries that were recognized as having broad application in buildings (i.e. carpets, wall coverings, fracture-resistant glass, systems control for energy consumption and the like). As we begin to plan for a comprehensive Technology Transfer mechanism it behooves us to recognize how earlier technologies evolved and to support a hastening of communication between various industries that will lead to more rapid product or system development.

The meetings hosted by the House, Science & Technology Committee over the past year have been useful in attempting to focus interested sectors of the building community on the programs and activities of the Department of Energy. Many private sector groups now have a better understanding of what DOE would like to do, and what it is capable of doing. Unfortunately, not enough time was set aside during the workshops to provide similar views on private sector research initiatives which, in aggregate dollar volume, dwarf DOE investments by a factor of 10 or more. An exchange of views on private sector R&D initiatives would be valuable and such information could be used to help frame BERD R&D priorities. If this begins to sound like a suggestion that these workshops be continued and better structured, that is just was is intended. NIBS has offered to assist DOE and the Committee with the administrative tasks of continuing the three-day discussions on a semi-annual basis.

Without question, the DOE BERD program has suffered from the following:

1) lack of consistency in budget authority to allow fulfillment of long range goals and objectives,
2) lack of staff resources and a continual eroding of knowledgeable staff manpower,
3) lack of ability to plan integrated research efforts relative to private-sector R&D programs as no mechanism is being used to facilitate this communication,
4) internal management problems that make it difficult for responsible contractors and consultants to devote significant amounts of time and energy to DOE program directions.

The so-called 5-year plan that was developed several years ago and undergoes an annual revision and update is in serious question. We are unable to discern the relationship of the plan to private sector R&D activities and we sense a lack of commitment to the plan on the part of agency officials. A new plan, taking into account information from private sector R&D entities, should be developed along with time tables and cost estimates that would facilitate better decisions on BERD resource allocations.

With regard to specific programmatic areas within BERD that should be supported or enhanced, we believe there is justification for stronger DOE involvement in 'Whole Buildings' research. So many questions have been raised as to the meaning of "whole buildings" research and so much concern has been expressed by Department officials, as evidenced by proposed budget reductions, that little value is placed on these activities. Please understand that in the design and construction business, reliable information on how materials, systems, and equipment perform is the basis for many decisions made by designers, owners, builders, contractors, manufacturers and others. The type and reliability of performance information is directly related to the liability of the decision maker, whomever he is and at whatever level in the decision-making chain. In construction there are at least three broad areas of liability that are of concern:

1. Professional Liability
   (associated with the designer's errors and omissions exposure),
2. Construction Liability
   (associated with the contractor's ability to perform, control, warrant and repair his work),
3. Product Liability
   (associated with a manufacturer's ability to guarantee a material or product for a specific use and at no risk to the general public).

Under the assumption that most large buildings are uniquely designed, and unique unto themselves, then every existing building is a laboratory containing potentially useful data and information about the performance of materials, systems and equipment used therein. As such, data can be drawn from a building and analyzed for its impact on future decision-making.

Such data can be useful in helping to shape advances in materials and equipment (product evolution) and reduce the risk to designers, contractors, and producers as we begin to better understand the problems and the solutions to such problems as they are presented.

In the area of equipment research, we note that many of the areas recommended for DOE involvement during the Airlie workshop are already programmed activities within the BERD Building Equipment Division. Based upon earlier NIBS statements before this committee we would agree that fewer funds should be made available in the appliance standards area, and that greater emphasis is needed in technology and consumer products.

I would like to take this opportunity to again direct the Subcommittee's attention to the NIBS' authorizing legislation and to the fact that Congress intended the Institute to become an authoritative source of information on building codes, standards, and new technology. In 1983, based upon a recommendation contained in the March 1982 report entitled "National Program Plan for the Thermal Performance of Building Envelope Systems and Materials", the Building Thermal Envelope Coordinating Council (BTECC) was established under the aegis of the National Institute of Building Sciences as a voluntary organization composed of representatives of both the public and private sectors. The mission of BTECC includes the stimulation and coordination of research, development, and verification of technology as it relates to the thermal performance of housing and building envelopes--that is.

- the materials, components, and subsystems that go together to make-up the thermal envelope.
- the thermal envelope as a whole.
- the interface between the envelope and mechanical/electrical subsystems.
- those aspects of total building performance such as fire

> safety, indoor air quality, and thermal comfort that affect and are effected by performance of the envelope.

> It does not include management or direction of research, development, and verification projects and programs per se.

Many private sector companies and individuals have joined in this effort to identify and quantify ongoing building energy research. In operation for just under one year, BTECC is growing rapidly and has its own Board of Direction fashioned after the NIBS' Board of Directors, broadly representative of the building community. It is our desire to see this Subcommittee and the Department of Energy play active roles in seeing that some financial support from federal sources be provided to match contributions and membership dues from the private sector. Thus the Council will become a viable partnership between government and industry who share the common goal of expanding our knowledge in building science.

Mr. Chairman, members of the Subcommittee, thank you for inviting our views on this important matter and please contact the staff at the National Institute of Building Sciences if additional information is needed. I will be happy to respond to any questions you have at this time.

Thank you.

Mr. LEWIS. Thank you, Mr. Marshall.

Mr. Vonier.

## STATEMENT OF THOMAS VONIER, PRESIDENT, THOMAS VONIER ASSOCIATES, INC., ON BEHALF OF THE AMERICAN INSTITUTE OF ARCHITECTS

Mr. VONIER. Thank you, Mr. Chairman, members of the subcommittee.

I am going to, if I may, with your permission, depart from the written statement. I am going to ask that it be entered in the record.

I would also like to point out that the copies provided previously were in the wrong sequence, so I have brought a correct copy which I will make available to the reporter. To any of you who have tried to read it, I am sure you have discovered that.

In my oral remarks, I would like to begin with a brief summary statement and make, I think, five points which reiterate essentially what is in the testimony, the written testimony.

I am an architect active in Washington, DC, and Baltimore. I am here today on behalf of the American Institute of Architects.

I became registered to practice just shortly after the 1973 oil embargo. Early on in my career, I was fortunate to have an association with Buckminster Fuller, now dead, whose name is probably known to you, and as a native of a State where Frank Lloyd Wright was very active during his life, I think I came to the profession with a certain sensitivity about resources among which energy soon became chief.

Mr. LEWIS. Is that building low-hung doorways and things like that?

Mr. VONIER. That is right. But I am only 5-foot-8, so that was never a problem for me. [Laughter.]

I worked for an architectural firm in London, England, at the time of the 1973 oil embargo. I was in London for the period right after the embargo, and I was amazed there at how easily the English people seemed to be able to accommodate what amounted to a fairly severe shortage for them. Now, I was told that a lot of that was the Dunkirk spirit, and I suspect there is some truth in that, but I think a lot of it also had to do with the plain fact that their buildings, their community systems, essentially could function without very much energy much more readily than our own.

I later went on to work for a firm in Vienna, Austria, and then one in Paris, France, and I found essentially the same was true in those countries of Europe; that is, that their buildings and community systems could do with essentially a great deal less energy.

Here, even after a decade, it seems to me that it has been much more an uphill proposition in the building industry. We have had a longer way to go, and frankly, I think we have made less progress in getting there.

I think today, as I come before you, I am concerned that we are probably as vulnerable now as we were 10 years ago in the event of a supply disruption, and I am even more concerned, I think, that a substantially increased proportion of the available income to most people is being spent for energy. I don't think that is necessary.

So I want you to understand that my remarks essentially come out of a very strong commitment, which is personal that conservation and the use of renewable energy resources in buildings is an important priority for this country. It is good for jobs; it is good for the economy; it is good for the environment; and I think it is good for our position in the world.

It has not to do only with the question of costs and how much we spend for energy; it has to do with the quality of life as far as I am concerned. Therefore, I think it is important that our Federal Government, by example, by clear vision, by an aggressive research program, do all it can to bring us into a better position in the building industry.

I think this subcommittee by and large agrees—at least that has been my experience in observing your appropriations in the past—so it seems to me that what I have come to talk about today is the means by which we do that.

Last year, I think we were in the mode of saving the budget, because there was none originally proposed, and this year, we have a budget but I am concerned about the program that stands behind that budget. I think the program stems mainly from what our colleague from the oil heat industry identified earlier as a commitment to long-term, high-risk generic research, and I would like to say that I think, in contrast, perhaps, to what my colleague, Mr. Marshall, has said, the real place where help is needed, it seems to me, is in the knowledge industry, knowing how to design buildings and doing it in a manner that produces results that are meaningful.

Now, I am the first to agree that new materials, new devices, and new systems have a part to play, but I will also argue that they cannot do everything. I will also argue that private entrepreneurs, private industry, is doing a great deal in the area of materials development, system development, and will continue to do so.

We need leadership and help, I think, in the development and evaluation of applications of those systems. "Whole buildings," I guess, is the label that has been attached to that kind of activity, and I hope to elaborate on that in just a moment. So it is not just a matter of components and subsystems, from my point of view.

To my five points: The first two are related, I think. In the whole buildings area, I think one could call whole buildings by another name. It might be systems integration; it might be system interactions. No matter how you call it, though, I think it is the activity of looking at components, new materials, new subsystems in the context of complete and real projects, projects that are exposed to weather, to people, to the influence of the other systems in the building. In a sense, it is the opposite of looking at components and materials in isolation.

To me—and, I believe, to my colleagues in the architectural and engineering professions—this is really the only convincing and persuasive basis on which one can evaluate the performance of new ideas. It is the only way that mirrors, in a sense, the real way that buildings go together out there in the world.

In the fiscal year 1985 budget, it looks to me like the administration wants to eliminate whole buildings. Our position is simple: We want more in whole buildings, especially, I think, in multifamily residential areas, small- and medium-size office buildings, and in the area of warehouses. And particularly important, I believe, are whole building or systems interaction questions related to humid climates.

I had hoped Mr. Fuqua would be here. I was going to point out to him that in his home State of Florida, the problem of cooling in a humid climate is paramount, and we see estimates from the Bureau of Census saying that over the period between now and the year 2000, fully 40 percent of the growth in southern tier State population is going to be in areas that are hot and humid. That is an area where we have a lot of work to do in both new construction and existing buildings.

Whole building assessments, system interactions, new design concepts, and evaluation of entire assemblies of components and materials are important in this area.

We think, also, that whole buildings research is going to have to look again at the current state of practice in the industry. It has been 5 years since reports were issued on the state-of-the-art in practice on any meaningful basis. It is probably more like 10 years since the material really looked at the buildings, since much of what was reported on in the work for the building energy performance standards was reporting on buildings just around the period 1974 and 1975.

Finally, I think in the area of whole buildings, the whole question of user behavior, of the responses of occupants in buildings to new systems, to different kinds of comfort control systems and new applications of materials is essential. The only way it can be done, it seems to me, is in the context of entire buildings.

Now to the second related point which has to do with component research: I would observe that in the fiscal year 1985 budget proposal as sent by the administration there is an overemphasis on the materials and components areas. I don't mean to say that there should be none. I mean to say that some of that activity seems to me to be much more appropriate to the private sector. It is the sort of thing one might reasonably expect proprietary companies to do on their own. As I said earlier, we would like to see a greater emphasis placed on whole building questions.

The third area has to do with technology transfer. I, for one, am certainly pleased to see it receive the kind of emphasis it has in the budget. I do have a question related to the Energy-Efficient Building Center which is proposed. It is a little difficult to understand quite what that is meant to do. One wonders, given past experience in the area of federally sponsored information centers and things of the sort, whether this is really the wisest way to go about it.

To me the question of fellowships, which are also proposed, is apparently a very sound idea. One would hope, too, that in the fleshing out of plans in that area, the administration would find it possible to see to it that it is not just laboratory researchers who are involved in the program, but it is also people who are out in the field as practitioners working on the applied end. By that I mean architects, engineers, builders, developers, others in a position to influence real buildings in a very direct way.

Two remaining points. Point four deals with existing buildings. I have been a participant in both the Carmel and the more recent

Cockeysville, Maryland, conferences in which the subcommittee has graciously been a cosponsor. I think that has been a very valuable experience both times for all cosponsors involved. I think the DOE programs have benefited greatly.

One of the questions that came up in the more recent session had to do with what are the differences between the issues for new and existing construction. Essentially, people were saying, Well, what would you do differently if you were concerned with existing buildings?

My fourth point is simply that I do think existing buildings, that vast part of the stock that is out there and that is going to remain there, present substantially different issues in certain areas which are detailed to some degree in our written testimony, but principally in the area of building diagnostics and the ability to accurately assess the existing conditions in a building. I think a lot more work needs to be done in this area, and some of it is appropriate for the Federal Government.

Finally, in the area of community systems, I sit as chair of the AIA National Energy Committee group concerned with research priorities for architects. This is a new group, essentially. It has very direct grass-roots kind of involvement in it. For the second straight year, we have as one of our highest priority recommendations work in the area of developing tools for community planners, city managers, county managers, things of that sort, that help them to better understand the energy implications of various planning decisions. I am personally convinced that that is an area where a great deal more can be done. I am sorry to have seen DOE retreat from that area yet again this year, as near as I can tell.

I think that kind of work is beyond the capacity of most municipalities—all of them, actually—and it strikes me as a very important area for the Federal Government to be involved with.

Thank you very much for this opportunity. I am grateful to have had the chance. I would be happy to answer questions if there are any.

With me today is Albert Eisenberg, who is director of government affairs for the AIA.

[The prepared statement of Mr. Vonier follows:]

# STATEMENT OF
THOMAS VONIER, AIA
ON BEHALF OF
THE AMERICAN INSTITUTE OF ARCHITECTS
BEFORE THE
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

MARCH 1, 1984
WASHINGTON, DC

Good Morning, Mr. Chairman and members of the subcommittee. My name is Thomas Vonier, I am president of Thomas Vonier Associates, Inc., an architectural firm in Washington, D.C. I am here today on behalf of The American Institute of Architects (AIA), the professional association representing this nation's architects. I am an appointed member of the AIA's national energy committee, on which I serve as chairman of a working group concerned with the energy-related research needs of the architectural profession. I am also a director of the Washington, D.C. chapter of the AIA, one of the largest chapters in the country. I recently represented the AIA at both of the House Science and Technology Committee's workshops on Building Energy Research.

My testimony will focus on several aspects of the building systems research program, and the passive solar components of the building energy systems research program.

The AIA has maintained a deep interest in energy conservation as the least expensive and most effective means of assuring adequate energy supplies. Because of our professional expertise, we have a special commitment to energy efficiency in buildings.

As an organization, the AIA has supported conservation with specific actions. For a decade, we have promoted the economic and environmental benefits of minimizing energy consumption through the use of cost-effective energy design strategies. We have spent almost $2 million on an energy education program--Energy in Architecture--a workshop series that increases the proficiency of our members' energy design skills. Over 3700 design professionals have attended these workshops. We also have published, at a cost of $240,000, a desk-top reference series of 12 energy monographs covering such topics as daylighting, building envelopes, shading devices, glazing techniques, and photovoltaic applications for buildings. AIA's expenditures in educating architects about energy-conscious building design total $3.5 million.

Even though oil prices have stabilized, as the world experiences an oil glut and as OPEC's firm control on world oil markets has been shaken, we must not be lulled into thinking that no energy problem exists. The supply of fossil fuels is finite and continues to deplete. Alternate fuel sources can only fill part of the gap between long-term need and long-term supply. And the security of our supply, which comes in large measure from foreign sources, is subject to disruption. Thus, energy conservation remains our only sure means of energy use reduction, and must continue to be a basis of national energy policy. The federal government must play a central role in supporting and encouraging conservation efforts where private action is not feasible or effective. These efforts should include not only direct measures to bring about energy savings, but also research into ways to increase the amount of energy that these measures can save.

Significant reductions in energy use can be found in buildings. The building sector accounts for about 37 percent of the nation's energy consumption, and about 40 percent of that is attributable to non-residential buildings. Our experience indicates that today's designs for non-residential buildings can make them much more energy efficient than the designs of five years ago. DOE's own research has confirmed this, demonstrating that energy use can be cut by as much as 40 percent when every aspect of a building's design is examined for energy implications.

In this regard, the AIA supports $20.19 million for building systems under the building and community systems program, and $11.0 million for the passive aspects of the solar building energy systems research program. I want to emphasize that this $11 million is only for the passive solar program. Building systems would receive only $12.2 million in FY 1985 under the DOE budget recommendation, down from the FY 1984 appropriation of $13.9 million. Passive solar buildings research would receive only $5.5 million according to the DOE budget. This compares with $8.2 million for the current fiscal year.

The most important feature of both programs, from the AIA standpoint, is whole buildings research. The greatest amount of energy savings can be achieved during the design phase of a building's development, before components are fixed in place. Architects and engineers must have information on energy savings options while they are still determining the size, shape, orientation, and internal configuration of the building.

The AIA believes that the best information is obtained as a result of research into buildings as a whole, with reduced emphasis on their components in isolation. We strongly oppose DOE's recommendations to eliminate building system interactions from the budget both for Building Systems and Solar Buildings. Instead of whole buildings research, DOE plans to focus too much of its research on individual building components and material in both these programs. We believe that this approach is short-sighted and decidedly unhelpful.

Buildings, after all, are not just windows, doors, heating systems, and lighting existing in isolation. Rather thay are dynamic, complex systems with a great many individual elements working together. Only sophisticated systems analysis that relates one building component to another and that measures the performance of each component in the context of a building's entire performance can provide us with the energy-saving information that will really make a difference.

The AIA does not believe that the federal government should undertake those activities that private enterprise can successfully accomplish on its own. In the area of buildings and component research, a significant amount of private research is already underway on individual building features, much of it supported by private manufacturers. Whole buildings research is expensive. A thorough analysis of just one building type costs between $500,000 and $700,000. This is beyond the capacity of private entities such as architects and developers seeking energy saving information for their particular projects, and also outside the immediate interests of private materials manufacturers whose research efforts are directed toward their own products.

For the building systems' whole buildings research program, we urge $3.5 million. For the current year the program received $1.5 million. These funds would go primarily to expand the number of building types that can be examined. There are at least seventeen different building types of which only one has been studied. We should move quickly to the study of multi-family residential apartments, office buildings, and warehouses because of their special potential for energy savings through design. Funding should also go for a review of current architectural practices and techniques since it has been five years since they were last studied. In addition, we recommend that whole buildings research look into the effects of buildings occupancy on energy consumption.

We also urge another $3.5 million for the passive/solar buildings program of whole buildings research. This compares with $1.9 million appropriated for FY 1984. Under the DOE budget, only $500,000 would be proposed for FY 1985. The ability to integrate components and materials into successful designs is particularly important in passive solar buildings for the success of these buildings relies on the interaction of materials, components, and daylighting strategies and conservation techniques. To achieve energy savings these buildings do not depend on mechanical equipment to the same extensive degree as other buildings. The following types of solar buildings whole building research should be included for funding for FY 1985:

- Development of integrated passive systems and HVAC systems. Too frequently, conventional HVAC systems and passive systems are operated separately, which is a very difficult problem for larger scale nonresidential buildings. This would require $260,000.

- Combined Heating and Cooling Systems for Nonresidential Buildings should receive $180,000. Modular components are available for conventional HVAC systems. More research is needed on ways to combine passive heating and cooling components in modular combinations.

- Daylighting Systems should receive $350,000 in order to increase the use of daylighting in nonresidential buildings, the cost of daylighting systems needs to be reduced and such systems developed into modular components which could be easily integrated into buildings.

## Performance Monitoring and Building Equipment

Related to whole buildings research, are two other important AIA concerns--performance monitoring which is located under the solar buildings program, and building equipment research which is located under the building systems program. Architects must receive information on the performance of actual buildings to enable architects to evaluate the effectiveness of passive solar strategies when they are actually put to work in buildings. Although the Administration requests no funding for this effort, the AIA believes that $1 million is necessary.

With respect to building equipment research, the AIA is concerned that DOE is failing to place sufficient emphasis on such research for nonresidential buildings. In our view, $8.9 million should be provided for such activities as the development of improved indoor environmental control technology, improved dynamic building control strategies, low cost sub-metering, and improved analytical tools for design synthesis, along with the collection and analysis of building system performance data. Funds should also be allocated to development of improved distribution system configurations in order to offer better temperature and humidity control, which in turn increases the energy efficiency of the whole building system.

## Technology Transfer

The AIA supports a heightened effort to assure the transfer of technology under the building and community systems and under the solar building programs. We seek $4.5 million for the former, the same as the Administration request, and

$750,000 for the latter, which the Administration proposes. The DOE technology transfer program, under the building and community systems programs would include funding for an Energy Efficient Building Center and establishment of a fellowship program. We do not believe that the DOE recommendations will effectively meet the objective of this program activity, which is to ensure that research results are communicated to user groups such as industry groups, private organizations, state and local jurisdictions, the financial community, and utilities. The Administration proposal will in fact diminish the extent to which this target audience can be reached. We have serious doubts that the building community will use an energy center, and we cannot see the justification for an expenditure of $2 million for 50 fellowships at $40,000 each.

Instead, we believe that the funding should be used to work with organizations and associations, provide consumer information, educate the financial community about the benefits of energy conservation, and to conduct workshops and training sessions for state and local government agencies.

For example the passive solar energy program initiated a technology transfer program with seven building industry associations, including the AIA and the National Association of Homebuilders. More worked is needed so that associations can take research results from the passive solar program and package it into formats suitable for their members.

The building systems program has a separate line item for research utilization. This activity concentrates on transfering research information to individual practitioners in the field. Products that these individuals can use in their daily practice include software packages, workshops on daylighting and lighting, articles for trade and professional journals, studies of regional architecture, and handbooks. In FY 1985, DOE plans to spend three percent of its $12 million building systems budget on financial utilization, which contrasts sharply with the $1 million appropriated in each FY 1983 and FY 1984. The AIA proposes that $2.8 million instead of $.3 million be appropriated for next year.

Mr. Chairman, this concludes my testimony. I am happy to answer any questions.

Mr. LEWIS. Thank you, Mr. Vonier. I hope I am saying your name right.

Mr. VONIER. That is correct.

Mr. LEWIS. Mr. Knobel, in its report to Congress last year, the EES Advisory Board stated that without adequate funding and congressional and executive commitment to a meaningful EES conservation program, it is our recommendation that the EES in its present form be abolished.

What, in your judgment, constitutes adequate funding?

Mr. KNOBEL. Well, Mr. Chairman, to the first part of that question, we are not looking at a $10 million program as such, because during the past year there was an additional $12.2 million of overcharge money that States chose to put in that program. So we do have a more effective program than the $10 million program.

But as we look back over the years that had only the $10 million program, I am told by staff people and regional people that many States did seriously impair their energy programs because of that low level of funding. Now, that is up to some degree in those States that chose to do so.

To actually put a specific point on the level of funding is very hard to do because every State is different. But the board was of the opinion that the $10 million figure was at a rate that it perhaps should not be funded at all.

Mr. LEWIS. Do you agree with the recommendation of the first EES Advisory Board in 1979 that the program be funded at a $35 million a year level?

Mr. KNOBEL. Mr. Chairman, as the board has reviewed the EES program over the years, I think we have found that it is basically a very effective program. But we also believe that the EES was never intended to be an eternal program, and perhaps it has reached a degree of maturity. The inherent flexibility of the EES program has allowed the States to identify their needs and act accordingly.

Now, it was quite significant to us that when the $200 million of petroleum violation moneys were given to the States under the provisions of the Warner amendment, of which they could spend that money on five different areas and of which EES was one, that some of the States chose to add an additional $12 million to the program.

But even of more significance to us was that about half of the States chose not to add a single dollar to the support of their EES program, which meant to us that perhaps the services that EES offers in those States was not that high a priority. And since this is the case in half the States, when they had the chance to add additional funds and didn't do it, maybe it is time to return this program to the States and allow those States that have effective programs and have the need to seek funding for it in that manner.

Mr. LEWIS. As you know, there is now a mandated 20 percent cost-sharing requirement for the EES service program. To the best of your knowledge, how effective have the States been in meeting this requirement?

Mr. KNOBEL. It is a little hard to identify on the—I think they are in-kind costs, but to the best of my knowledge, they have met that. I am informed there is one State whose legislature is contemplating zero funding of the 20 percent, which means they will not be accepting the Federal money. I will not be prepared to identify that State until that becomes fact, but I am told that that is a process in one State.

Mr. LEWIS. Have any States had to cancel their program in light of——

Mr. KNOBEL. The lack of the 20 percent?

Mr. LEWIS. Yes.

Mr. KNOBEL. No.

Mr. LEWIS. The committee has heard a great deal of criticism in the past about the overlap and duplication in the DOE outreach programs, especially among the EES service—the Residential Conservation Service, the Conservation and Renewable Energy Inquiry Hotline, et cetera. Do you believe that this criticism has now been addressed?

Mr. KNOBEL. Will you repeat that statement again, sir, just the question?

Mr. LEWIS. Yes. I have it written, so I will read it slower.

The committee has heard a great deal of criticism in the past about the overlap and duplication in the DOE outreach programs, especially among the Energy Extension Service, the Residential Conservation Service, and the Conservation and Renewable Energy Inquiry Hotline. Do you believe that this criticism has now been addressed, or does the telephone hotline essentially provide the same service to EES?

Mr. KNOBEL. Well, this was one of our concerns, the duplication of existing services. It appears that there has been a genuine effort on the part of DOE to identify all of the Federal programs which are even far more inclusive than the ones you mentioned, to identify which ones of those are involved in energy conservation.

But I really do not have the indication that there is a lot done with the information after it is gathered. So I am not so sure but what there is a degree of overlap yet.

Mr. LEWIS. In your report last year, you recommended that Congress conduct a review of EES to determine whether its continuous service was to the public interest. At what level of funding and under what organizational structure would you recommend?

Mr. KNOBEL. We requested that, and to my knowledge, that was not done.

Mr. LEWIS. What was the rationale for the recommendation?

Mr. KNOBEL. We wanted to know what the attitude of the Congress was. That is precisely what the question is.

Mr. LEWIS. What could be learned that was not covered by the DOE-sponsored evaluation of the program in 1982 or the GAO report of the management of DOE's Information and Outreach Programs?

Mr. KNOBEL. I again respectfully ask you to repeat the question, sir.

Mr. LEWIS. What could be learned that was not covered by the DOE-sponsored evaluation of the program in 1982 or the GAO report on the management of DOE's Information and Outreach Programs?

Mr. KNOBEL. I don't believe I am prepared to answer that, sir.

Mr. LEWIS. All right. Then what is your view of DOE's decision to request no funds for EES in fiscal year 1985, but to initiate a new set of technological transfer activities instead?

Mr. KNOBEL. Sir, that goes back to the area that we believe it may be best—maybe the maturity has come to the point where the States should take over the EES in those States where they have viable programs. But a technology transfer program would necessarily have to be an ongoing nationwide endeavor which would have to be a function of the Federal Government.

Mr. LEWIS. Mr. Carney, do you have any questions?

Mr. CARNEY. Thank you, Mr. Chairman.

Mr. Lynch, how effective has the DOE Oil Combustion Program in Brookhaven been?

Mr. LYNCH. Well, I tried to indicate as briefly as possible in the remarks that it is difficult to compare it to other programs because there is no other. So comparing it on its own merits, without reflection on any other types of programs that might be competitive or duplicative or something where you could compare it, it has been tremendously effective. It is the only effort that has been made that has been effective.

We talk about outreach programs. We talk about technology transfer. This may not be high tech in terms that you usually think of Brookhaven as a nuclear research facility, but indeed, these more practical applied research activities at Brookhaven have been the only activities, and they have been effective, but it has been over a very short period and it has been at a very low cost level.

We talk, for example, about refiner overcharge funds flowing back to States. I sit here this morning and I hear $200 million, $35 million for this, $40 million for that, and I am thinking that we have 20 percent of the American homes, and I don't think there has been a million dollars a year spent for 5 years, and that is the level of effort, and all of this is not at Brookhaven, I am sure, so you can see that it is an extremely modest effort, and what it really shows is, not only has it been very effective, but the promise of what that could be if there were some stimulation of that is exciting.

Mr. CARNEY. I am talking about how effective has the research been. We have a program going on where we are doing burner tests, that type of thing. What kinds of results have they produced?

Mr. LYNCH. Well, let me try to explain this way. They have not tried to develop new burners, to the best of my knowledge. What they have tried to do is to identify the institutional barriers to getting more efficient equipment into the hands of users. That requires them to talk with regard to technology and technology transfer.

The first thing faced by consumers is, should we—how do I believe this? Ever since there has been the oil embargo in 1973, everybody is selling something that is going to save you everything. You know, we are all exposed to it. And the consumer is greatly confused. How do they believe what is and what is not?

One of the first things that Brookhaven was able to identify through their lab programs, which is just one tiny part, was to determine that the potential of oil heating equipment was not as it was generally understood by architects, engineers, the general public, regulators; that it is a dirty, inefficient method that is obsolete and should go by the boards. Now, of course, that was encouraged by the gas utilities, the electric utilities, the coal people, the solar people, and just about anybody else that had anything going.

But Brookhaven determined, oh, my gosh, this stuff has a potential, with very little stimulation, of being 85 percent seasonally efficient, which was astounding and a total turnaround. And that kind of discovery which was done through the lab directly and done there at Brookhaven and nowhere else in the world, turned around everybody's understand of what the potentials were and why people could make a modest investment to install these appliance improvements and save money and reduce oil use.

So that was a specific thing where you are talking about testing. Another one was, everybody comes forward with a brandnew piece of equipment and a miracle, you know, a new carburetor that will do anything. Brookhaven served in that capacity by saying, Well, bring your things here and we will look at them. They weren't going to act as judge, but they were going to sift through and provide the feedback to industry of what works and what does not. So that was a second great move that they made that did not result in making brandnew miracle types of equipment. That was left to industry to do.

Mr. CARNEY. Have you ever been there?

Mr. LYNCH. Oh, yes.

Mr. CARNEY. They have had combustion studies; they have utilized new innovative burner techniques; they have reduced the fuel consumption.

Mr. LYNCH. Yes.

Mr. CARNEY. They have accomplished this. I have been to that particular lab, the burner lab, on several occasions, and some of their accomplishments are outstanding.

Mr. LYNCH. Yes.

Mr. CARNEY. My problem is that your industry has not taken advantage of that, and I wonder if your industry is perhaps being selfish. Why aren't those technologies in the homes now? We have seen that.

I am not so sure that there might be a different motivation here, because I think the program has been an absolute success, but what we have failed to do now is to put that program in everybody's house, and I am not so sure that your industry might not want those programs in everybody's house. That is what my concern is, Mr. Lynch.

Mr. **Lynch**. Well, your concerns are unfounded. The very fact that our industry was the one that came to the House Science and Technology Committee originally to get the funds to get Brookhaven moving, when no one else ever thought of it, and when——

Mr. **Carney**. Well, why aren't we putting those burners in people's homes to cut down their consumption?

Mr. **Lynch**. It is very simple. There are a number of complex factors, and in that particular market, if you want to talk about that, it is very simple. This equipment has got to overcome people's ideas and concepts that have been built into their heads, that using oil is bad; it is unpatriotic; that you should go to electric. That was the policy of the U.S. Government in Project Independence. Then we came with nuclear, and nuclear was going to make electricity too cheap to measure, and why pay any attention to these others? You just get yourself electric. And these are the impediments that consumers face, and to make an investment out of their pocket—this is not like a commercial enterprise.

Mr. **Carney**. Mr. Lynch, as far as consumers are concerned, there are consumers that have no choice but to go to oil or electric, and you don't have to educate any consumer, at least in my congressional district, which is cheaper, oil or electric. I happen to live by Brookhaven Laboratory, and I know what the expense of electric heating is, and I know what the expense of oil heating is, and I am not so sure that we haven't had the breakthroughs of oil burner efficiencies, and they haven't been brought down to the level of the consumer.

That is not the program's problem; that is the industry's problem. And I wonder if there is not a problem within the industry. That is all I am saying.

Mr. **Lynch**. My answer to that, Congressman, is no, and the answer to it can be verified by the number of installations, and we could do it for your area directly, and I think that is probably the best way to answer you, is for us to get you some of that information, and we would be pleased to do it, and you will be surprised at the fact that, as I said, tens of thousands of those installations have been made, and they are modest in cost, and our industry has been the sole—our level of the industry. I am not speaking for major oil companies. I said in my remarks that they don't involve themselves.

But the marketer, the person who serves that account, has been the sole promoter of all of these conservation efforts, which are against his own best interests, as you well pointed out, because that means less fuel use, but we are doing it. We are doing it.

Mr. **Carney**. Well, now we are getting down to a very important point. Hasn't that program at Brookhaven proven that with modifications—and I am not talking about this year or last year; I am talking about 4 years ago——

Mr. **Lynch**. All right.

Mr. **Carney** [continuing]. haven't they proven that there is like a 39-percent advantage to putting in some of the technologies that they have tested at Brookhaven? A 39-percent drop in fuel consumption and maintain a house on Long Island or anywhere at the same temperatures as they were before by putting these different techniques, by applying the types of oil burner heads and that sort of thing? Hasn't that been proven 4 years ago?

Mr. LYNCH. No, and it is much more modest than that. I wish I could affirm that, but the improvement in efficiencies has been in the area of 16 percent on flame retention equipment, for example, and as high as 20 to maybe even 22, 23 percent if entire systems were replaced. So it is much more modest, but it is still very important.

Mr. CARNEY. We will give the 16 percent; I stand corrected. I am not so sure, but I will say 16 percent, and that is a modest adjustment; that is a modest change that has to be made.

Mr. LYNCH. Yes.

Mr. CARNEY. It can be made in an existing oil burner in someone's basement.

Mr. LYNCH. Exactly.

Mr. CARNEY. Why in the world aren't those technologies or those changes being put into homes?

Mr. LYNCH. Well, I am saying to you that they are. Do you see? I am saying to you that they are. The new standard in our industry for the last 5 years, 6 years, has been the flame retention equipment, which was demonstrated—not invented, not researched and developed—but confirmed at Brookhaven, that that was the desirable level or plateau to get to, and indeed, Congressman, that is the industry standard and has been these last 3 or 4 years. You cannot buy the oldstyle equipment any more.

Mr. CARNEY. Wouldn't we be better off to switch now, as a committee, to put an emphasis on consumer education, to get those things out to the consumer?

Let me ask you another question, Mr. Lynch. How much further do you think that the program at Brookhaven Laboratories can reduce—you know, the burner program at Brookhaven Laboratories—can reduce the amount of consumption to produce $x$ amount of BTU's?

Mr. LYNCH. I think there is a great deal of work to be done, and the examples of that are quite simple. Some of the newest technology that we could reach for that would get us that 39 percent you are talking about, for example, means going to condensation mode, and I don't want to get to high tech talk, but what it really means is reducing the stack temperature that goes out the chimney and heats the neighborhood but not the house. You reduce that, and the flue temperature gets below the dew point, and when you get below the dew point, it turns to water, so you get rain in your chimney, and so forth, and that is very bad. It rots out the chimney, rots out the equipment. But that condensation mode holds this great potential. What do you have to do? You have to get to—and in the gas industry, they leaped to it. It is called pulse combustion.

But why not oil? It was in oil first. And the answer is that the oil industry does not have the applied research program for that. The gas industry has that in place. So they moved to it. We sit there in the bleachers unable to bring that step forward, and that is one of the things we would love to see encouraged at Brookhaven, because we don't know whether our materials of boiler and so on will stand up under these corrosive types of conditions when the condensation occurs.

I don't mean to get technical about it, but the potentials are there, and that is what I mean when I say there is so much more to do.

Mr. CARNEY. How much of the research in that area in the gas industry was done by AGA?

Mr. LYNCH. I think they are doing a lot of it now because they are finding all the problems that we knew were there in the first place with regard to what happens with condensation, and they are kind of doing a double take and going back and saying, Well, now, let's fix it, after having jumped into it.

Mr. CARNEY. That is the AGA that is doing that?

Mr. LYNCH. No, I would rather imagine that DOE has done a fair amount of work on that as well, but certainly not related to our fuel or our products.

Once again, there is no place for them to do that within our industry. There is no place to coordinate it. And we have relied on it entirely; this entire 20 percent of American homes is relying on this tiny, modest effort.

Mr. CARNEY. Let me say to you that I have a heck of a lot more than 20 percent of my homes relying on oil heat, and I am a supporter of the program at Brookhaven National Laboratory, but what I am distressed with is what we have been able to come up with over the years, and that basic knowledge is not out in the field.

If we are going to spend Federal dollars on any program, whether it be with oil burners or whether it be with space programs, that don't ultimately get down to the benefit of the people, then we are wasting taxpayers' dollars.

I am wondering when the types of findings we have made in that program at Brookhaven will eventually get down to the consumer who is paying a heck of a lot to heat his home.

Mr. LYNCH. Congressman, that was one of the goals that was assigned by this committee, the House Science and Technology Committee, for this project. That was one of the goals: find the institutional barriers and overcome them.

Unfortunately, we do have the problems in a research facility like Brookhaven and at DOE under the new policy where they say, Well, we don't want to get involved in this kind of thing. We want to get into high tech. We want to get into long-term generic things that will bring us a Nobel Prize. We are not interested in these things that are down here, getting down to commercialization.

Mr. CARNEY. I would disagree with you. The demonstration home at Brookhaven Laboratory is not going to win a Nobel Prize. The transmission program is not going to win a Nobel Prize. That has to do with cutting costs to the consumers. I can give you one—you said it is a nuclear laboratory. It is a multidisciplinary laboratory that does a heck of a lot of applied work that is not going to go out and win Nobel Prizes. They do an awful lot there, but sometimes we don't see it get transferred over for the taxpayers' benefit.

Mr. LYNCH. And I say to you again, if you will examine what the original mandate was to Brookhaven to identify those things, part of that was the technology transfer and consumer education, and those things, unfortunately, are not considered high tech by DOE.

I consider the work that was done by DOE, by Brookhaven—and that is what is in my testimony—to be remarkable that a nuclear research facility could and would do this type of work, and it has been tremendously effective.

Mr. CARNEY. It is not a nuclear research facility. It is a multidiscipline national laboratory.

Mr. LYNCH. All right. It is remarkable that this multidiscipline national laboratory could find the interest to pursue and to follow through on this, But it is difficult for them to do with DOE saying, we want to go into generic long-term, high-risk ventures. It makes it very difficult for them to accomplish their task.

Mr. CARNEY. Mr. Lynch, I think we might be at a point in time where the people in the Federal Government are saying, we are making some of these applied breakthroughs; we are proving these applied technologies; but the industry is not picking it up. That is what I am trying to say. Maybe you should be looking in your own house as well as looking into what we are doing as a Federal Government. That is what I am trying to say.

I yield back the balance of my time.

Mr. LEWIS. Thank you, Mr. Carney.

Mr. Lynch, it was recommended at the DOE workshop to do a better job of monitoring energy efficiency brought about by burner retrofits and disseminating the information to the oil marketing industry. These questions are more in line with what Mr. Carney and you were just discussing. Do you agree with that recommendation?

Mr. LYNCH. Well, I think that it is vital. I have made those recommendations at a DOE research conference I related here in my remarks. I said that it was imperative that the DOE act as the stimulator of a coordinated industry activity, especially when they have the overview and see that the industry is fragmented and see the facts that I have stated, that the major oil companies who make the fuel don't want to be involved and won't be; that the manufacturers of the equipment have so little money that they have to put it on what they think the fastest horse is; and so these facts are simple; they are elementary; and they are well known.

I am saying that the Federal Government, if they are going to spend any money here—and they should—that they ought to do it in order to overcome those difficulties we have in the industry in order to get all the way down to the consumer and do what Congressman Carney wants done.

The only thing I could say is that never in any of the work that you have done or funded, none of it has been as productive per dollar as the amounts of money that have been spent for this, and I don't think there is any other area of activity that they have done that has been funded at this low level.

So you put the combination of those two things together, and the fact that it is our industry, the marketers of the fuel at the local level, who have volunteered to come forward and say, We need it for the consumer, and we want you to recognize that.

In Mr. Carney's area, that is 8 out of 10 homes that are relying on that.

Mr. LEWIS. I wish he was here to hear you say all that.

Mr. Lynch. And in Florida, which everybody thinks is all sunshine, I know, there are a vast number of oil-heated homes. They have different sets of problems because they are trying to work with kerosene, and the equipment is right in the living space, which gives other kinds of indoor air quality problems. There is a whole range of these things that really should be looked at.

Mr. Lewis. You made the statement of pulse combustion furnaces. Do you think DOE's oil-fired combustion equipment research should focus on developing new or more efficient systems such as the pulse combustion furnaces, or continue to retrofit the existing systems?

Mr. Lynch. Certainly the most important thing—and I agree with our colleague from AIA—is that we cannot, simply cannot, take our eye off the existing stock of housing. That is where people live; that is where they are paying their bills; that is where they are going to be.

It is much easier to make energy improvements either in the shell of a house or in the systems or the development in a new house because you are going to make an investment anyway; you might as well do it the right way, the modern way, and in the most up-to-date manner.

And so I think that emphasis has got to be on the existing stock, certainly, for the consumer. I don't think that DOE needs to invent anything. What they need to do is show that the Government is interested in this area and that they will bring the parties together and that they will stimulate that and they will identify the barriers that are the holdups, and if it is research in this area, or if it is an education area here, or if it is a technology impediment over here, that they would identify it and use a rifle, not a shotgun, but use a rifle on those individual impediments.

Mr. Lewis. Thank you, Mr. Lynch. I appreciate that.

I guess we just have one question for Mr. Marshall and Mr. Vonier, but I would like to point out something. You mentioned that little was done during the past decade as far as conservation for buildings and this sort of thing, and I think—I am from Florida, as well as the chairman.

Mr. Vonier. I beg your pardon.

Mr. Lewis. Well, that is all right. But I want to point out something that I think you all messed up on, and I think you lacked a lot of credibility when we came out with the Federal legislation and the various AIA groups allowed this to be applied to the various building codes throughout the States and the counties. In Florida, you have basically two States, north of Orlando and south of Orlando. Last night it was like 20 degrees in Tallahassee, but in Miami it was around 55, and that is sort of prevalent down there with cold fronts.

But the Federal legislation that was adopted—I forget what it was, the acronym for it—but the same code was adopted for the northern part of Florida as the southern part—no windows, no sliding glass doors, same kind of windows, if they use them, with storm shutters. It was ridiculous, and we had a problem with that, and a lot of States went ahead and, instead of using it as a guideline, just adopted it, and in doing so, it created a tremendous upheaval in the building industry as well as people, because it was adding $1,500 or $2,000 to homes just in the small homes in Florida.

That happened in 1978, and here we are just a few years later. So I think that you all should have more or less applied your influence to make sure that the proper building application for winterization and weatherization of homes in certain parts of Arizona and certain parts of Florida was certainly different than New Hampshire and Vermont. But they all came out the same.

I just wanted to make that comment. But for both you and Mr. Marshall, the committee has been extremely interested in the problems relating to indoor air pollution. Do you believe that EPA and DOE are working effectively together in establishing a program in this area, and what would you recommend in this area?

Mr. **Marshall**. Mr. Chairman, as far as the National Institute of Building Sciences is concerned, we believe that there is still room for some additional improvement in working on this problem. We feel that one of the best ways to do this is to bring the parties to bear on the subject, both the Federal and the private sector, to address this problem.

NIBS has this capability of helping in this area. We are certainly proposing to EPA a program that we hope will come to fruition, that will help in this area.

Mr. **Lewis**. Do you care to comment, Mr. Vonier?

Mr. **Vonier**. I would. I do want to say that the AIA has very strong interest in the problems of indoor air quality and I think is likely to be a proponent of having DOE and EPA work well together to get information out that will help people understand how they can overcome some of these problems.

I am pleased that the committee is taking an interest in this area.

Mr. **Lewis**. Thank you.

Apparently, there are not going to be any more questions, so I would like to thank you gentlemen for coming before the subcommittee and providing your testimony. Your written testimony will be made part of the record.

If there is no further business, this committee will stand in recess.

[Whereupon, at 12:16 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

[Additional material submitted for the record follows:]

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SOLAR ENERGY INDUSTRIES ASSOCIATION Suite 800 1001 Connecticut Avenue, NW Washington, DC 20036 202 293 2981

SEIA

April 27, 1984

To: The Honorable Don Fuqua
Chairman
Energy Development and Applications Subcommittee of the
House Science and Technology Committee

Dear Mr. Chairman:

I appreciated the opportunity to appear before the Energy Development and Applications Subcommittee of the House Science and Technology Committee on 1 March 1984 to represent the Solar Energy Industry Association (SEIA) for the purpose of discussing the 1985 Solar Thermal Appropriations for the Department of Energy (DOE).

During my presentation to the Subcommittee, Congressman Sensenbrenner posed some questions for his colleague, Congressman Winn, concerning McDonnell Douglas Corporation's (MDC) Dish/Stirling Electric Program (see Enclosure (1) which outlines Congressman Sensenbrenner's questions). Although I appeared before the Subcommittee in my capacity as chairman of the SEIA Solar Thermal Division, the questions were directed to me as a representative of MDC. I am also Manager - Solar Energy Program Development for MDC and am therefore providing responses to Congressman Sensenbrenner's questions. I very much regret the delay in responding.

1. MDC and United Stirling A.B. (USAB) of Sweden have entered into an exclusive cooperative endeavor agreement to undertake joint development of an economically competitive commercial configuration of a solar power system utilizing a parabolic dish solar collector and a Stirling engine power conversion unit. This development program is based entirely on private venture capital and involves a substantial shared investment and risk for both MDC and USAB. Under the agreement, MDC has, in effect, an exclusive license with a right to sub-license from USAB for the use of its Stirling engine technology and patents with respect to solar power conversion units. USAB is developing other applications of Stirling engines and, therefore, may sell Stirling engines without restriction to any third party for application in any area other than solar power conversion. In turn, MDC agreed that it will not purchase Stirling or similar heat engines for solar power conversion units from other than USAB. This aspect of the agreement between MDC and USAB protects the interests of each party in relation to their significant shared investments in the joint development program.

2. The timetable outlined by the DOE in the Small Community Project at Osage City, Kansas, is not compatible with the schedule for the Dish/Stirling development program established by MDC and USAB under our cooperative endeavor agreement. Therefore, MDC currently does not plan to submit a bid to the DOE for the Small Community Project at Osage City. The technical milestones set forth in the development program must be met to assure technical integrity of our Dish/Stirling power system before MDC will consider bidding on any DOE projects similar to the demonstration project at Osage City. Furthermore, if MDC and USAB attempted to respond to the DOE program schedule, that would divert critical resources from our commercial development programs, delay our commercial program, and increase our investment risk significantly.

3. In the event the DOE proceeds with the Small Community Project at Osage City without altering the timetable, there should be no lack of bidders for the Project. There are other firms possessing parabolic dish technology and there are also firms other than USAB that produce engines suitable for use in the solar power conversion area, that is, there are available alternatives to MDC's dish and USAB's Stirling engine.

4. If the DOE were to consider changing its timetable for the Small Community Project at Osage City to allow delivery of a prototype system during 1986, MDC would welcome the opportunity to discuss with the DOE the possibility of a bid, once MDC's Dish/Stirling has met the technical milestones under the development program established by MDC and USAB. However, MDC would consider involving the local utility at Osage City to operate a demonstration system as a part of the MDC development program. In this case, it might be possible for DOE to provide support directly to the utility to underwrite specific demonstration costs. Either approach would likely result in a significantly lower program cost for DOE.

The above points answer Congressman Sensenbrenner's questions regarding the MDC-USAB cooperative endeavor agreement and reflect MDC's current reason for not submitting a bid to the DOE on the Small Community Project at Osage City. If you have further questions, we will be glad to respond.

Very truly yours,

Frank Duquette
Manager, Solar Energy Program Development

Chairman
Solar Thermal Division

**BLACK & VEATCH**
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March 2, 1984

Representative Don Fuqua, Chairman
House Committee on Science and Technology
Subcommittee on Energy Development and
Applications
Room B374
Rayburn House Office Building
Washington, D.C. 20515

Dear Representative Fuqua:

By this letter, I am requesting your permission to submit the attached written testimony for insertion in the record of the Subcommittee on Energy Development and Applications held on Thursday, March 1, 1984.

This testimony is in support of the industry-recommended DOE solar thermal budget for FY85.

Thank you for your consideration. In the event of any questions you may contact me at (913) 967-2554.

Very truly yours,

J. C. Grosskreutz
Manager, Advanced Technology Projects

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Attachment (2 copies)

# Solar Thermal Central Receiver
# Development Plan
# For
# Molten Salt Technology

Written Testimony
For
March 1, 1984 Hearing

SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS

COMMITTEE ON SCIENCE & TECHNOLOGY

U. S. House of Representatives
Washington, D. C.

by

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## 1.0 INTRODUCTION

This testimony is presented in support of the industry* recommended solar thermal budget for FY1985. Specifically, I am presenting a plan for continued and systematic development of solar central receiver technology that reflects the views of the design team for solar repowering of Arizona Public Service Company's Saguaro Unit 1. The use of solar thermal energy remains a potentially viable option for the production of electric power at levels (60-100 MWe modules) attractive to the electric utility industry located in southwestern United States. This valuable resource is renewable, non-polluting, produces clean, high temperature heat and, once the capital investment for conversion to electricity has been made, results in stable energy production costs. When the solar central receiver technology is sufficiently mature and the end product is cost competitive, utilities will consider it seriously in their generation expansion plans as part of a balanced and mixed energy resource system.

The federal solar thermal program started in 1973 under National Science Foundation auspices as a research effort. In the intervening 10 years, the program has made significant progress toward reducing the technical and economic risks associated with the solar central receiver technology. Experiments conducted at the Central Receiver Test Facility (CRTF) in Albuquerque, and results now being obtained from the Solar One Pilot Plant near Barstow, California have added greatly to the reduction of these risks and our knowledge and definition of the key problem areas. In addition to risk reduction, the CRTF experiments have also developed attractive heat transfer media alternatives to the water/steam system used at Solar One. Among these alternatives, molten salt, a compound consisting of 60% sodium nitrate and 40% potassium nitrate, is a leading candidate for combining temperature (1050°F), storage, and cycle conversion efficiency capability.

We believe that the molten salt-based solar thermal technology and the user industry can be best served by a well-conceived plan which brings that technology to the point of maturity required for industry acceptance and use, thereby allowing a fundamental, sound approach to financing. This plan requires significant federal support, but will result in the availability of this new technology to the nation and its producers and consumers of electricity.

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*Solar Thermal Division of Solar Energy Industries Association (SEIA).

The development plan presented here reflects the current easing of world-wide oil supplies with respect to demand and allows for a rational step-wise evolutionary approach to solar thermal technology development.

## 2.0 BACKGROUND

Solar central receiver technology has evolved through several development steps. The most visible of these, Solar One, located near Barstow, CA, has demonstrated the viability of the central receiver concept using water/steam to transfer solar energy to the turbine-generator. As previously mentioned, other important experiments have identified molten salt as a highly attractive heat transfer media.

Small scale (5 MWt) molten salt receiver and steam generator subsystems have been designed and tested at the Central Receiver Test Facility (CRTF) in Albuquerque, New Mexico. At the present time a Molten Salt Electric Experiment, also 5 MWt, is being tested at CRTF. This experiment will produce 750 kWe of electricity by a steam turbine-generator coupled to a molten salt receiver, storage and steam generator subsystems. It represents the first system-level development step along the evolutionary path to mature large scale central receiver plants using molten salt technology.

At the same time as these molten salt experiments have been conducted, designs for utility scale plants have been carried out for the purpose of 1) defining and resolving critical technical issues through the design process and 2) establishing supportable cost estimates for construction and operation of these plants. Conceptual and preliminary engineering designs have been carried out for a 60 MWe molten salt central receiver plant at Arizona Public Service Company's Saguaro Station, some 40 miles northwest of Tucson, AZ. The current design is for repowering Saguaro Unit One; however, an independent 60 MWe solar plant, located adjacent to the Saguaro units, has also been considered and the economics compared to the repowering option.

In either case, it is the conclusion of the APS design team (APS, Black & Veatch, Martin Marietta and Babcock & Wilcox) that substantial project subsidies, in the range of 35-65% of total construction costs, are required to generate a return on investment that is acceptable to either third-party or utility ownership. The further conclusion of the APS design team is that reduction and eventual elimination of these subsidies is possible by means of a continuation and expansion of the current molten salt experiments at CRTF plus intermediate-scale experiments which combine to reduce both the technical risks and costs for eventual utility-scale plants. To this end, a Molten Salt Central Receiver Development Plan has been prepared and is summarized in this testimony.

## 3.0 MOLTEN SALT TECHNOLOGY DEVELOPMENT PLAN

The Molten Salt Technology Development Plan is presented here in terms of its objectives, structure and milestones, and the experiments to meet these objectives.

### 3.1 Objectives

The Development Plan has two broad objectives:

1. To provide a sound basis for evolving the molten salt solar central receiver technology to maturity acceptance by power producers and financial institutions.
2. To proceed with technology development through a series of discrete scale-up steps that are selected on the basis of
    - satisfying a demonstrable need,
    - least cost consistent with obtaining the desirable results, and
    - a schedule that leads to operation of a large, utility-scale experiment by the early 1990's.

### 3.2 Structure and Milestones

The Plan is structured around specific scale-up objectives, and the definition and scheduling of the specific experiments to accomplish the desired scale-up to utility size modules (60-100 MWe). The scale-up objectives are divided into two broad categories: those having to do with 1) critical subsystems and components and 2) the total plant system. These specific objectives can be summaried as follows.

1. To verify the design, performance and reliability of critical molten salt subsystems and components at appropriate sizes.
    a) Solar Receiver
        -- Model scale: 5 MWt
        -- Intermediate scale: 30-90 MWt
        -- Utility scale: 190-300 MWt

b) Hot Storage Tank
  - Model scale: 7 MWh
  - Intermediate/Utility scale: Appropriate sizes to be determined by analysis.

c) Pumps, Valves, Heat Tracing, Instrumentation, and Salt
  - Model scale
  - Full, Utility scale

2. To verify the design and to obtain operating experience for the total plant system.

a) Performance (net kWhrs produced/month, year) and reliability (scheduled and forced outage rates)
  - Model scale: 5 MWt/0.75 MWe
  - Intermediate scale: 30-90 MWt/10-30 MWe
  - Utility scale: 190-300 MWt/60-100 MWe

b) Operating strategy and procedures
  - Model scale: 5 MWt/0.75 MWe
  - Intermediate scale: 30-90 MWt/10-30 MWe
  - Utility scale: 190-300 MWt/60-100 MWe

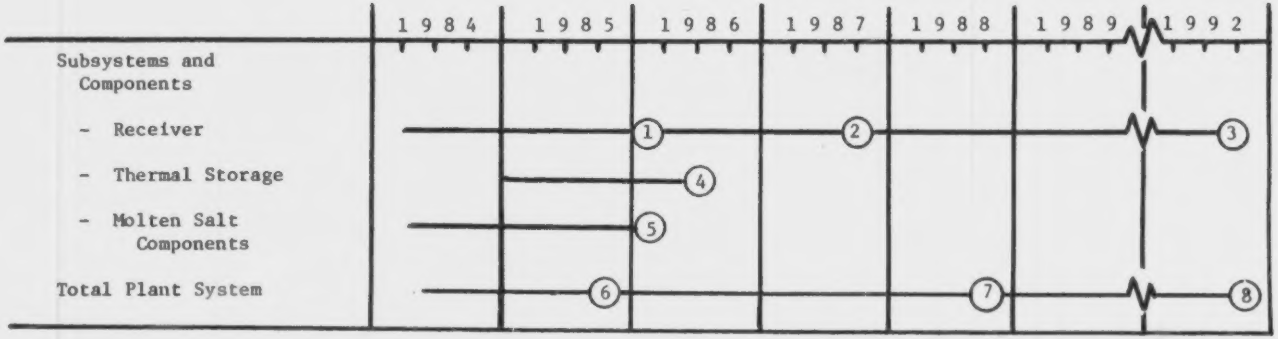
The milestone schedule for meeting these specific objectives is shown in Figure 3.2-1.

### 3.3 Experiments to Meet the Objectives

Most of the specific, model-scale objectives listed under (1) above, as well as full-scale pump and valve verification are already being met by cost-shared experiments currently underway or planned at the CRTF. Other model-scale experiments are yet to be designed and funded. These, plus initiation of the intermediate scale objectives and their corresponding experiments are candidates for FY85 funding.

Our recommendations for extension of two model-scale experiments and a description of the required intermediate scale experiments are given below.

- Molten Salt Electric Experiment (MSEE)-Phase III. This experiment is a one year extension to the present Phases I and II now underway at the CRTF. The objective of this Phase III is to gain longer term operating experience with the model scale molten salt system now installed there (5 MWt; 0.75 MWe), and to surface reliability problems.



Milestones

① Design and 6 Months Performance Verification @ 5 MWt Level.

② Design and 6 Months Performance Verification @ 30-60 MWt Level.

③ Design and 6 Months Performance Verification @ Utility-Scale, 190 MWt, Level.

④ Hot Tank Design, Performance and Lifetime Verification.

⑤ Performance and Lifetime Verification @ Utility-Scale Level for Pumps, Valves, Heat Tracing and Instrumentation.

⑥ Complete 1-1 1/2 years of operating experience @ 5 $MW_t$ Level.

⑦ Begin 2 year Operating Experience at Intermediate-Scale 10-30 MWe Level.

⑧ Begin 2 year Operating Experience at Utility-Scale 60 MWe Level.

Figure 3.2-1. Summary Milestone Schedule

- Expanded "Category B" Tests. These experiments are additions to those now underway at CRTF and are required to complete the tests at the model-scale level for additional, critical subsystems and components. Specifically, they are the following:
  - -- 6 months - 12 months extended lifetime testing of the model receiver.
  - -- 6 months - 12 months extended pump and valve testing at full scale. Data is required under both hot (1050°F) and cold (530°F) conditions.
  - -- extended testing and experience with heat tracing and salt line instrumentation.
  - -- new experiments with molten salt storage tanks to test a small-scale version of the preferred full-scale design for resistance to thermal cycling and leak detection methods.
  - -- extended monitoring of molten salt properties, including the addition of additivies for lowering the melting point and raising the operating temperatures.

We recommend scale-up from the model system size to an intermediate level prior to fielding a full, utility-scale system experiment. The intermediate scale experiment consists of two phases as described below.

- Intermediate Scale Subsystem and Component Experiment. The need to design and test a molten salt receiver at the 1/6-1/3 utility-scale size is the basic reason for this experiment. The lessons learned from the Category B model receiver (1/40 scale) would be applied to this larger design. Two possible sites exist for performing this experiment. The first is at the Barstow Solar One site where a field of heliostats capable of delivering 30 MWt of thermal power already exists. Modification of the Solar One plant would consist mainly of replacing a portion of the heliostat mirror modules and erecting an additional tower at the south boundary of the collector field for mounting the molten salt C-cavity receiver. In addition, a molten salt transport and storage system would be required. The second site is on land adjacent to the Arizona Public Service Company's Saguaro Station. This site offers complete support facilities and the availability of an operating and maintenance staff. While requiring a new heliostat field for this experiment, this site has the added advantage of potential future expansion of the intermediate scale experiment into a full, utility-scale experiment.

- Intermediate Scale Total Plant System Experiment. The need to design, test and operate a total plant system at the 10-30 MWe scale is the reason for this experiment. It is a logical expansion of the Intermediate Scale Subsystem and Component Experiment described above and requires the addition of a steam generator and a turbine-generator subsystem.

Completion of these Intermediate Scale Experiments would achieve two major milestones in the development of molten salt central receiver technology. A full assessment of the results would then be made to support decisions concerning the deployment of a utility-scale experiment at the 60 MWe level. The most important objective of the utility-size experiment is to verify the predicted performance of the plant in terms of the number of kilowatt-hours of electrical energy generated on an annual basis. This number is crucial to verifying the predicted revenue stream and economic viability in the eyes of the utility and investment community. Arizona Public Service Company feels that its Saguaro Plant is a potential site for this utility size experiment where the solar steam can be used by the existing Unit One steam turbine or by a new, independent electric power generating subsystem (EPGS). By using the existing 120 MWe turbine at Saguaro, APS could easily accommodate expanding the intermediate scale experiment to a utility-scale experiment with no additional EPGS cost. This site has the advantage of being an existing station with complete support facilities, a dedicated operating and maintenance staff, available land for the collector field and offers the least cost route to all parties for implementing the required utility-scale experiment.

## 4.0 PLAN IMPLEMENTATION

The milestones of most importance shown in the Major Milestone Schedule, Figure 3.2-1. are:

- design and performance verification of the molten salt receiver at the 30-60 MWt level by October 1987;
- the start of total plant system operation at the 10-30 MWe intermediate level by late 1988;

- the start of total plant system operation at 60 MWe, the utility-scale level, in the 1992 time frame.

For the present, the planning horizon extends only through the first two intermediate scale milestones. We believe that their achievement will maximize the potential for both a successful utility-scale experiment and for subsequent market acceptance of molten-salt technology without the need for further subsidies.

Implementation of the extended model-scale experiments and intermediate scale experiments described in Section 3 will require Federal participation on a significant scale. It is appropriate that Federal subsidy of these experiments occur to reflect the continued willingness of the United States public to share the risks of developing solar technology. To understand better why this risk-sharing is necessary, some historical perspective is helpful. The risk-taking entrepreneur in most new technologies has been the hardware manufacturer who stood to recapture his venture capital with significant gain. Examples are television sets, integrated circuits, computers, etc. In each of these, a consumer product can be clearly identified, manufactured and marketed. In contrast, a solar thermal electric plant is a system composed of many subsystems: solar collectors, solar receiver/boilers, thermal storage, heat exchangers, turbine generators, and a host of interconnecting piping, controls, wiring and buildings to contain it all. No one company manufactures, tests and markets all of these subsystems. That is why modern fossil-fired, central electric generating stations have required well over 50 years to develop, with the cooperation of manufacturers, utilities and design engineering firms all required to advance the state of the art.

For nuclear-powered electrical generating systems, significant penetration of the private sector required about 30 years, with very large Federal involvement in the riskiest subsystems: enriched fuel supply, reactor development, materials selection, quality control and safety, system control, spent fuel processing and radwaste storage. The last two areas are still not free enough of risk to attract private investment. The strongest support for nuclear system development came from the nuclear submarine program, fully funded by the Federal government.

With this background perspective, the need for continued Federal involvement in the development of solar thermal systems for delivery of electricity is based on the following.

- There is no one industry or manufacturer that will take the risk of complete solar thermal systems R&D because no one industry will ever market complete utility systems and hence profit from manufacturing the entire system.
- For a group of industries to spread the development risk among themselves, they must be assured of a predictable market for their subsystems to be integrated into complete solar thermal electric systems.
- To generate the market required for individual company risk investment, the system users (e.g. utilities) must be convinced of system performance, reliability and competitive electricity production.

The critical step in this sequence is convincing the user and investor that reliable operation, performance and reasonable O&M costs are possible. We believe that implementation of the Development Plan for Molten Salt Technology described in this testimony to be the best means for achieving this critical step, and that it warrants the serious consideration and support of the Federal government.

The resources required to implement the Model-scale and Intermediate Scale Experiments described in Section 3.3 have been estimated based on current information available from on-going experiments and engineering design studies. The costs tabulated below are total costs and are in the neighborhood of what we believe to be necessary. The Intermediate Scale Experiments are assumed to be 30 MWt/10MWe in size and sited at Saguaro.

| Major Activities | Total Estimated Costs by Federal Fiscal Year (millions of as-spent dollars) | | | | Totals |
|---|---|---|---|---|---|
| | FY85 | FY86 | FY87 | FY88 | |
| MSEE-Phase III | 1.4 | | | | 1.4 |
| Expanded "Category B" Tests | 5.1 | | | | 5.1 |
| Intermediate Scale Experiments | | | | | |
| a) Subsystems and Components | 5.1 | 30.2 | 20.5 | | 55.8 |
| b) Total System Expansion of a) | | | 29.9 | 23.0 | 52.9 |
| Totals | 11.6 | 30.2 | 50.4 | 23.0 | 115.2 |

The funds for the MSEE-Phase III and the Expanded Category B Tests have been included under "Advanced Molten Salt Component Development" in the recommended budget of the Solar Thermal Division of SEIA. The Intermediate Scale Experiments are candidates for the funds labeled "Industrial Team Projects" in the SEIA recommended budget.

## 5.0 SUMMARY AND CONCLUSION

Solar thermal central receiver plants for electric power generation currently require subsidies in the form of tax credits and direct federal participation to attract market interest. A technology development plan for molten salt central receivers has been presented that is based on the steps needed to achieve a technical maturity and a degree of economic certainty required to eliminate the need for such subsidies. The total plan consists of a series of discrete scale-up experiments that leads to operation of a large, utility-scale experiment (e.g. 60 MWe) by the early 1990's. The development plan described herein places emphases on

- extension and expansion in the scope of model-scale (5 MWt) molten salt subsystem and system experiments now underway at the DOE Central Receiver Test Facility in Albuquerque, NM, and
- implementation of intermediate scale experiments to verify the design and performance of molten salt receivers, storage tanks, and steam generators at the 30-60 MWt level, with subsequent expansion of these experiments to include electric power generation at the 10-30 MWe level. This expansion will allow verification of performance, reliability and operating strategies of the total plant system.

Implementation of these model and intermediate scale experiments will require significant Federal funding support to the involved solar industrial participants. This Federal support will reflect the willingness of the public to share the risks of developing solar central receiver technology as part of a balanced and mixed energy resource system for electric power generation.

# FISCAL YEAR 1985 DEPARTMENT OF ENERGY AUTHORIZATION

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## TUESDAY, MARCH 6, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Development and Applications,
*Washington, DC.*

The subcommittee met, pursuant to notice, at 9:35 a.m., in room 2318, Rayburn House Office Building, Hon. Frederick C. Boucher (acting chairman of the subcommittee) presiding.

Present: Representatives Boucher, Sensenbrenner, Schneider, Bateman, Lewis, and Carney.

Staff present: Robert S. Kripowicz, staff director; and William T. Harvey, minority energy coordinator.

Mr. **Boucher**. The subcommittee will come to order.

Today is the first of 3 days of hearings on the Department of Energy's fiscal year 1985 fossil energy research and development budget request. The request is for programs that will allow the clean and efficient burning of coal, the conversion of coal to fuels which can substitute for dwindling oil and gas supplies, and that will enhance the amount of oil, gas, and oil shale reserves available for energy use. The largest portion of the $273 million budget is for work in coal related technologies. I think this is particularly important because of the vast and underutilized reserves of coal that we have nationwide.

Notwithstanding the fact that the administration's request this year is more in line with previous congressional action than have been its prior submissions, the subcommittee is still concerned about the low level of funding and the progress which is being made in a number of program areas. Today's witnesses will address a number of areas of interest to the subcommittee.

The first panel will address progress and needs in coal combustion technology for utility applications. These witnesses will also address coal research and development from an industrial perspective.

Our second panel will provide testimony on fuel cell technology. In this area, the Department of Energy has dramatically reduced the level of funding for technology development from previously approved congressional levels. Fiscal year 1984 appropriations were almost $47 million, and the Department has requested only $16 million for fiscal year 1985.

We are pleased to have these distinguished witnesses appearing before us today, and we will now proceed with the first panel.

[The opening statement of Mr. Boucher follows:]

# OPENING STATEMENT
# OF THE
# HON. FREDERICK C. BOUCHER (D-VA.)
## SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
## HEARING ON
## FY 85 DOE AUTHORIZATION FOR FOSSIL ENERGY R&D
MARCH 6, 1984

TODAY IS THE FIRST OF THREE DAYS OF HEARINGS ON THE DEPARTMENT OF ENERGY'S FISCAL YEAR 1985 FOSSIL ENERGY RESEARCH AND DEVELOPMENT BUDGET REQUEST. THE REQUEST IS FOR PROGRAMS THAT WILL ALLLOW THE CLEAN AND EFFICIENT BURNING OF COAL, THE CONVERSION OF COAL TO FUELS WHICH CAN SUBSTITUTE FOR DWINDLING OIL AND GAS SUPPLIES, AND THAT WILL ENHANCE THE AMOUNT OF OIL, GAS, AND OIL SHALE RESERVES AVAILABLE FOR ENERGY USE. THE LARGEST PORTION OF THE $273 MILLION BUDGET IS FOR WORK IN COAL RELATED TECHNOLOGIES. I THINK THIS IS PARTICULARLY IMPORTANT BECAUSE OF THE VAST AND UNDER-UTILIZED RESERVES OF COAL THAT WE HAVE IN THIS COUNTRY.

DESPITE THE FACT THAT THE ADMINISTRATION'S REQUEST IS MORE IN LINE WITH PREVIOUS CONGRESSIONAL ACTION THAN ITS PRIOR SUBMISSIONS, THE SUBCOMMITTEE IS STILL CONCERNED ABOUT THE LEVEL OF FUNDING AND THE PROGRESS BEING MADE IN SEVERAL PROGRAM AREAS. TODAY'S WITNESSES WILL ADDRESS SEVERAL AREAS OF INTEREST TO THE SUBCOMMITTEE.

THE FIRST PANEL WILL ADDRESS PROGRESS AND NEEDS IN COAL COMBUSTION TECHNOLOGY FOR UTILITY APPLICATIONS, INCLUDING THE USE OF FUNDS FOR A LARGE DEMONSTRATION PLANT. WITNESSES WILL ALSO ADDRESS COAL RESEARCH AND DEVELOPMENT NEEDS FROM AN INDUSTRIAL PERSPECTIVE.

OUR SECOND PANEL WILL PROVIDE TESTIMONY ON FUEL CELL TECHNOLOGY. IN THIS AREA, THE DEPARTMENT OF ENERGY HAS DRASTICALLY REDUCED THE LEVEL OF FUNDING FOR TECHNOLOGY DEVELOPMENT FROM PREVIOUSLY APPROVED CONGRESSIONAL LEVELS. FISCAL YEAR 1984 APPROPRIATIONS WERE ALMOST $47 MILLION, AND THE DEPARTMENT HAS REQUESTED ONLY $16 MILLION IN FISCAL YEAR 1985.

WE ARE PLEASED TO HAVE THESE DISTINGUISHED WITNESSES APPEAR AND WILL NOW PROCEED TO THE FIRST PANEL.

Mr. BOUCHER. While the panel is being seated, without objection, the prepared statement of Mr. Winn will be inserted in the record at this point.

[The opening statement of Mr. Winn follows:]

# STATEMENT OF THE HONORABLE LARRY WINN, JR.
# ENERGY DEVELOPMENT AND APPLICATIONS SUBCOMMITTEE
# HEARING ON
# FY 1985 DOE AUTHORIZATION FOR FOSSIL ENERGY
MARCH 6, 1984

THANK YOU, MR. CHAIRMAN, FOR THIS OPPORTUNITY TO WELCOME OUR WITNESSES TODAY. WE LOOK FORWARD TO THEIR TESTIMONY AND DISCUSSION OF THE FY 1985 DEPARTMENT OF ENERGY AUTHORIZATION REQUEST FOR FOSSIL ENERGY R&D.

DURING THE PAST SEVERAL YEARS WE HAVE SEEN A DRAMATIC CHANGE IN THE FOSSIL ENERGY PROGRAM, BOTH AS TO ITS CONTENT AND TO ITS COST. SEVERAL YEARS AGO THE INTENT WAS TO BUILD AND OPERATE BOTH PILOT PLANTS AND DEMONSTRATION PLANTS TO EVALUATE VARIOUS COAL UTILIZATION AND CONVERSION PROCESSES. THESE PLANTS WERE EXPENSIVE. UNDERSTANDABLY, AS WE BECAME MORE INVOLVED IN REDUCING FUNDING LEVELS, IT WAS NECESSARY TO RE-THINK THE FOSSIL ENERGY PROGRAM.

WHEREAS EARLIER WE INTENDED TO BUILD AND OPERATE LARGE FACILITIES FOR ACQUISITION OF EMPIRICAL DATA, IT WAS DECIDED TO CHANGE TO A MORE FUNDAMENTAL, BASIC RESEARCH-ORIENTED PROGRAM. IT WAS BELIEVED AT THAT TIME, AND IT STILL IS, THAT ACQUISITION OF DATA UNDER THE LATTER CIRCUMSTANCE WILL, IN THE LONG RUN, PROVIDE MORE MEANINGFUL INFORMATION. THE UNFORTUNATE CIRCUMSTANCE, MR. CHAIRMAN, IS THAT WITH ALL THE MONEY SPENT ON FOSSIL ENERGY TO DATE, WE HAVE FEW IF ANY PREDICTIVE PROCESSES FOR COAL CONVERSION AND UTILIZATION.

THIS MEANS THAT IF WE HAVE A PROCESS, SUCH AS GASIFICATION, ON WHICH WE HAVE SUCCESSFULLY DEMONSTRATED A PARTICULAR COAL, WE CAN ONLY RUN ANOTHER COAL TO DETERMINE HOW IT WILL REACT IN THAT PROCESS. WE DO NOT HAVE THE CAPABILITY TO PREDICT HOW THAT COAL WILL BEHAVE.

IT APPEARS TO ME THAT THE INDUSTRY HAS ADAPTED ITSELF FAIRLY WELL TO THIS CHANGE IN R&D PHILOSOPHY. INDUSTRY CANNOT JUSTIFY CONDUCTING RESEARCH ON LONG-TERM, HIGH-RISK PROCESSES SINCE NO FORSEEABLE RETURN IS POSSIBLE. THEREFORE, THE FEDERAL GOVERNMENT DOES HAVE AN APPROPRIATE ROLE. THE PROBLEM OCCURS AS THE PROCESS IS SPONSORED TO A POINT WHERE, LOGICALLY, INDUSTRY SHOULD PICK UP THE ACTIVITY AND EXPENSE. THAT TIME AND THE EXTENT OF SPONSORSHIP ARE DIFFICULT TO DEFINE AND COULD LEAD TO MUCH CONTROVERSY AND DISCUSSION. HOWEVER, IN TIMES SUCH AS THESE, WITH SIGNIFICANT BUDGET DEFICITS, IT IS NECESSARY FOR THE FEDERAL GOVERNMENT TO MAINTAIN AS SHORT AND INEXPENSIVE AN INVOLVEMENT IN ANY PROCESS AS POSSIBLE. THAT IS A PROBLEM WE SHARE WITH THE DEPARTMENT OF ENERGY, WITH ITS CONTRACTORS, AND WITH ALL THE INDUSTRIES WHO ARE INTERESTED IN OUR ACTIVITIES.

AGAIN, MR. CHAIRMAN, WE WELCOME THESE PEOPLE TODAY AND WILL CERTAINLY FIND THEIR INFORMATION BENEFICIAL.

Mr. BOUCHER. We would ask at this time that Mr. Michael High, the director of the division of energy demonstrations and technology for the Tennessee Valley Authority; Dr. Richard Wolfe, the director of research and development at United Coal Co.; Dr. George W. Roberts, the director of commercial development for the Air Products and Chemicals, Inc.; and Mr. Kurt Yeager, vice president of coal combustion systems for the Electric Power Research Institute come forward.

Gentlemen, we are pleased to have you with us today. I would remind the witnesses that the full text of your statements will be made a part of the record, and it is therefore not necessary for you to read your entire testimony and that if you desire to do so, you may merely summarize.

We will begin with Mr. Michael High.

## STATEMENT OF MICHAEL D. HIGH, DIRECTOR, DIVISION OF ENERGY DEMONSTRATIONS AND TECHNOLOGY, TENNESSEE VALLEY AUTHORITY

Mr. HIGH. Thank you, Mr. Chairman. I am Michael High, director of the division of energy demonstrations and technology for the Tennessee Valley Authority. That is a fancy way of saying I direct research and development for the electric part of TVA. I appreciate the opportunity to address this committee this morning on TVA's experience with the atmospheric fluid bed combustion and TVA's plans for a demonstration facility for this technology.

Let me first describe very briefly for the committee what the atmospheric fluid bed combustion technology is, and I will refer to this as AFBC so I don't have to repeat that tongue twisting title.

AFBC is a coal burning process which provides a method of burning coal economically and in an environmentally acceptable manner. TVA sees this technology as an alternative to conventional coal-fired steam plants which require complex add-on environmental control technologies in order to meet emission standards.

AFBC also has the potential to offer the utility industry lower cost electricity generation and the ability to meet or exceed present environmental requirements when directly burning a variety of abundant or less costly coals.

Inherent to the AFBC process are a number of desirable features. Sulfur dioxide, an undesirable product of burning coal is captured by calcium oxide formed from the limestone in the bed, thus removing the need for scrubbers. This by-product is called calcium sulfate, and when dehydrated is nothing more than gypsum plaster.

Department of Energy studies have indicated that this dry solid by-product may have useful applications or, at the least, provide a material which can conveniently be disposed of in an environmentally acceptable manner. In addition to the capture of sulfur, the formation of nitrogen oxide is significantly reduced since the operating temperature of the fluidized bed is around 1,550 degrees Fahrenheit. By comparison, a conventional pulverized coal burning plant operates at roughly twice this temperature and results in higher nitrogen oxide.

Equally as important, we believe, as the environmental control capabilities are the cost advantages offered by the AFBC process. The highly efficient heat transfer characteristics of boiler tubes within the fluidized bed allow efficient steam production even at the lower temperatures. The need for flue-gas scrubbing equipment is eliminated, and the particulate capture can be done with commercially available processes such as baghouses. These attributes result in capital cost projection for the AFBC plants which are estimated to be less than those for a conventional coal-fired plant equipped with flue-gas scrubbers and electrostatic precipitators. Without the additional flue-gas scrubber equipment, and the personnel required to operate it, and with the ability to burn lower cost high sulfur coal, operating and maintenance costs are also projected to be lower.

In September 1976, the TVA Board of Directors approved phase I of a project which would lead to the design and construction of a utility AFBC boiler powerplant. Contracts were awarded to three boiler manufacturers to obtain conceptual designs and cost estimates for a 200-MW demonstration plant boiler and at the same time, an 800-MW commercial AFBC boiler and its auxiliary equipment. In parallel with these contracts, TVA internally carried out preliminary designs and cost estimates for site specific studies such as coal and limestone handling, powerplant building, turbo generator, and other balance of plant facilities for a 200–MW boiler.

Using these cost estimates, we made an economic analysis considering the retrofit boiler, a stand-alone unit at an existing plant and a new plant at a new site. These cost comparisions to a conventional pulverized coal with wet limestone scrubbers indicated that indeed the AFBC plant could produce electricity at a cost of approximately 10 to 15 percent lower.

During the same timeframe, studies were initiated for the selection of a suitable site somewhere in the Tennessee Valley region on the TVA grid on which to locate the 200 MW stand-alone demonstration facility. As these studies were being conducted and as bench scaled AFBC results were becoming available, it was recognized by both TVA and the Electric Power Research Institute that a pilot plant which could be operated under utility conditions was needed in order to provide the engineering data, process performance verification, and equipment evaluations needed to design a large scale demonstration plant.

It was at this time that TVA recognized the need to revise our 1976 project plans for a program or a series of projects, activities, along with EPRI work to give us the best chance of developing this technology. The following discussion covers the essential activities under this plan.

To provide design confidence and the flexibility to test process improvements along with emission controls, TVA purchased a 20-MW AFBC pilot plant in September 1979. This plant is built at the TVA Shawnee Steam Plant site in Paducah, KY. The total facility cost through construction was $68.4 million.

This utility-oriented pilot provides TVA and the industry with means to show whether or not efficient and cost-effective performance of an AFBC boiler and its related auxiliary systems can be obtained under electric utility operating conditions. These conditions demand larger fluctuating steamflows and more stringent steam conditions than industrial boilers and the existing bench-scaled AFBC units.

The 20-MW pilot plant is complete and fully operational. Since the first coal fire in May 1982, the unit has accomplished over 5,000 hours of testing on high sulfur Kentucky coal with an average sulfur content of 4.2 percent. The AFBC boiler has operated exceptionally well and, in TVA's judgment, there has been no significant technology related problems. Process performance has been encouraging. The AFBC process can achieve in excess of 90-percent sulfur removal with a 4.2-percent sulfur coal. It can also achieve a combustion efficiency of greater than 97 percent within what we believe is an economically viable range of operating parameters. Additionally, the nitrogen oxide emissions are substantially lower than the new source performance standards and fall consistently in the range that are usually referenced for low NOX burners.

The pilot plant is equipped with several equipment configurations. These systems are being used to develop a data base for the 160-MW demonstration plant as well as to add to the already existing knowledge of AFBC. Additionally, an excellent opportunity exists to eventually use this pilot plant facility to establish a data base to compare a wide range of solid fossil fuels to enable design scale-up for the use of these fuels in AFBC utility boilers. This fuel diversification potential could markedly improve the Nation's chances of achieving energy independence.

Testing is being accomplished through a cosponsored $28.5 million contract for 42 months with the Electric Power Research Institute. That is 67 percent shared by EPRI and the remainder by TVA. There has been to date about $36.4 million in congressional appropriations expended on this project. We have spent $38 million in our own resources at TVA and EPRI has, to date, expended about $7.4 million in funds on the pilot.

Now, let me turn to the demonstration plant. The results of the conceptual designs contracted for in 1977 give TVA sufficient confidence that a large-scale AFBC plant could be built even though the need for the pilot plant was recognized. In September 1979, contracts were initiated with Babcock & Wilcox, Combustion Engineering, and Babcock Contractors, Inc., leading to preliminary cost estimates for the 200-MW demonstration. For each of these designs, TVA performed plant layouts, balance-of-plant designs, and prepared a preliminary draft environmental impact statement. The preliminary designs were a refinement of the earlier conceptual designs.

Similarly, a new AFBC concept was being explored during this time, and to ensure that an attractive option was not lost, TVA contracted with Combustion Engineering in conjunction with Lurgi-Chemie of Germany to prepare a conceptual design of a 200-MW circulating fluid bed combustion demonstration plant.

The work of the three boiler manufacturers was completed in January 1981, along with our evaluations of those plant designs, cost estimates, schedules, and other specifications. Although we were finished with the cost estimates for all the plants at the same time, we decided it was necessary to investigate what other options for demonstrations of the technology were available. This was trickier too, because of our load forecast and funding availability.

The retrofit configuration involves the dismantling of an existing boiler and replacing it with a new boiler, whereas an add-on consists of a new boiler and boiler building built adjacent to an existing one. A standalone plant offers greater flexibility, but based on these studies, it was determined that an add-on approach could adequately demonstrate the technology in a more cost-effective manner.

An AFBC boiler will be constructed beside an existing unit at our Shawnee steamplant as a replacement for that existing boiler. The AFBC boiler proposed will be capable of generating 160 MW electric and make maximum use of existing turbogenerator sits and other auxiliary equipment. The design fuel for the demonstration plant will be a high-sulfur Illinois basin coal, typified by the Kentucky No. 9 that we now burn in our pilot plant. Fuel flexibility will be considered with testing of alternate fuels during the test program.

TVA prepared a preliminary cost estimate of $200 million for the design, construction, and startup of this demonstration plant at Shawnee. It is anticipated that a 3- to 4-year test and demonstration period would cost another $20 million.

The current active principals in the project, TVA, Duke Power Co., the Commonwealth of Kentucky, and the Electric Power Research Institute are presently working on a schedule that will refine this cost estimate by mid to latter part of 1984, and we anticipate to begin detailed design before the end of this year.

In regard to the funding, a total of $30 million in deferred appropriations, $15 million in fiscal year 1985 and $15 million in fiscal year 1986, for TVA through the DOE fossil energy budget has been approved by the U.S. Congress for the construction of this facility. The principals have committed a total of $135 million to the project. Of this amount, Kentucky has committed $10 million, Duke Power $10 million, EPRI $75 million, and TVA $40 million. TVA's contribution will come from its self-financed power system as a research and development expense. In addition to this $40 million, TVA is providing a site, turbogenerator, baghouse, flue-gas stack, coal handling equipment, and other balance-of-plant equipment. Also, we have spent some $7.9 million on previous AFBC demonstration plant activities at TVA which will be of benefit to this project. Of this amount, TVA contributed $6.9 million in power funds and DOE contributed another $1 million.

Remaining funds are now being sought from utilities, foreign countries, State governments, coal companies, railroads, boiler manufacturers, and anyone else that is interested in this project. We have received indications of intent to join in financial participation in excess of $25 million from a number of these sources to date, and we expect to get the remaining required funds in the very near future.

Now let me turn to some of the supporting research and development activities that we laid out in the plan in 1979 to get on with this development. During the planning for the commercialization of AFBC, TVA, EPRI, and the boiler manufacturers, and others identified a number of technical areas that were critical to the development of the technology. Major areas identified were things like coal feeding, boiler construction materials, boiler control, recycling of fly ash, handling and disposing of waste products.

To address these areas, TVA has undertaken a substantial number of research and development projects over the last several years. We have pursued this aggressive program to assure that one, we had a pilot plant which we could operate and produce data in a timely manner and two, we could produce design data for larger scale plants. In fact, TVA has undertaken more than 50 research and development assessment and supporting tasks at a cost of some $7.6 million to date. Of this amount, we provided $7 million and have used $0.6 million out of appropriated funds. TVA was responsible for conducting the work or technically monitoring the work of contracts for these supporting tasks. A brief description of several of these supporting studies may be found in my written paper.

In summary, TVA has been interested in fluid bed combustion technology since 1975 and consequently has developed a broad base of experience. A total of 445 man-years of experience is evidenced in 125 design engineering, development engineering, operations, and technical management personnel. Many training courses, seminars, and conferences have been attended by my staff that are assigned to these projects.

From TVA's viewpoint, AFBC is an important and viable technology which can significantly benefit the Nation. The Federal support TVA received on a pilot plant allowed us to maintain an aggressive development program, and the technology deserves continued Federal support to ensure that its goals are achieved. The interest shown by the electric utility industry, as will be evident by Mr. Yeager's testimony, demonstrates an excellent example how the industrial sector and the Federal Government can be active partners in the research and development effort.

I appreciate the opportunity to present our views, and I would be pleased to answer any questions this committee has.

Thank you.

[The prepared statement of Mr. High follows:]

STATEMENT OF MICHAEL D. HIGH
DIRECTOR
DIVISION OF ENERGY DEMONSTRATIONS AND TECHNOLOGY
TENNESSEE VALLEY AUTHORITY
BEFORE THE
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
MARCH 6, 1984

Mr. Chairman, I am Michael D. High, Director of the Division of Energy Demonstrations and Technology of the Tennessee Valley Authority (TVA). I appreciate the opportunity to address this committee on TVA's experience with the atmospheric fluidized bed combustion (AFBC) of coal and TVA's plans for a demonstration facility using this technology.

AFBC is an advanced coal-burning process, which provides a method of burning coal economically and in an environmentally acceptable manner. TVA sees this technology as a near-term alternative to conventional coal-fired steam plants, which require complex environmental control technologies in order to meet emission control standards. AFBC appears to offer the utility industry a near-term solution for direct burning of a variety of abundant and less costly coals, lower costs for generating electricity, and the ability to meet and exceed present environmental requirements.

Inherent to the AFBC process are a number of desirable features: Sulfur dioxide, an undesirable by-product of burning coal, is captured by calcium oxide formed from the limestone in the bed, thus removing the need for a scrubber to produce calcium sulfate (gypsum plaster when hydrated).

Comprehensive Department of Energy studies indicate that this dry, solid by-product may have useful applications or, at the least, provide a material which can be conveniently disposed of in an environmentally acceptable manner. In addition, since the operating temperature of a fluidized bed is around 1,550°F, the formation of nitrogen oxides is significantly reduced. Conversely, a conventional plant operates at roughly twice the temperature, which results in higher nitrogen oxides.

Equally as important as the environmental control capabilities are the cost advantages offered by the AFBC process. The highly efficient heat transfer characteristics of boiler tubes within the fluidized bed reduce the physical size of the heat transfer surface in the boiler. The need for flue-gas scrubbing equipment is eliminated, and particulate capture with commercially available baghouses is enhanced. These attributes result in capital costs for AFBC plants, which are estimated to be less than those for a new conventional plant equipped with flue-gas scrubbers and electrostatic precipitators, once beyond the first-of-a-kind stage. Without the additional scrubber equipment and personnel required to operate the scrubber and with lower cost high-sulfur coal, operating and maintenance costs are also projected to be lower.

In September 1976, TVA's Board of Directors approved phase I of a project leading to the design and construction of a utility AFBC power plant. Contracts were awarded to three major boiler manufacturers

(Babcock & Wilcox, Combustion Engineering, and Foster Wheeler) to obtain preliminary designs and cost estimates for a 200-MW(e) demonstration plant boiler and an 800-MW(e) commercial AFBC boiler and auxiliary equipment. In parallel with these contracts, TVA internally carried out preliminary designs and cost estimates for the plant site, coal and limestone handling facilities, power plant building, turbine/generator, and other "balance-of-plant" facilities. Using these cost estimates as a basis, an economic analysis was performed considering a "retrofit" boiler, a "standalone" unit at an existing site, and a new plant at a new site. Cost comparisons to a conventional pulverized-coal plant with wet limestone scrubbers indicated that an AFBC plant produces electricity at a cost which is approximately 10 to 15 percent lower than that of a conventional plant with scrubbers. In addition, studies were initiated for the selection of a suitable site somewhere in the Tennessee Valley region on which to locate a 200-MW(e) demonstration facility. At an early date, it was recognized that a pilot plant, which could be operated under utility conditions, was needed in order to provide the design data, performance results, and equipment evaluations needed to design a demonstration plant. A conceptual design for a pilot plant was also completed. Since these initial studies, TVA's AFBC activities have evolved into three major project areas: (a) a 20-MW(e) AFBC pilot plant, (b) a 160-MW(e) AFBC demonstration plant, and (c) supporting research and development.

## 20-MW(e) AFBC Pilot Plant

Several small-scale AFBC development units built and operated by others continue to confirm the attractiveness of this technology, but none answer the many engineering design and operating questions which must be resolved before this technology can be used in a commercial-sized utility plant. Neither do they permit assessment of the full environmental impact of this technology. Consequently, to provide design confidence and the flexibility to test process improvements along with emission controls, TVA purchased a 20-MW(e) AFBC pilot plant in September 1979. The pilot plant is built on the TVA Shawnee Steam Plant site in Paducah, Kentucky. The total facility cost through construction was $68.4 million. This utility-oriented pilot plant provides TVA with the means to show that efficient and cost-effective performance of an AFBC boiler and related auxiliary systems can be obtained under utility operating conditions. These conditions demand more fluctuating steam rates and higher steam conditions than the planned industrial boilers and the existing bench-scale AFBC units. Site work was started in April 1980 and operational testing commenced in the summer of 1982. A cosponsored $28.5 million contract with the Electric Power Research Institute (EPRI) for operational testing of the pilot plant was signed in June 1980. Through December 1983, there has been $36.4 million in congressional appropriations, $38 million in power funds, and $7.4 million in EPRI funds expended on this project.

The pilot plant is considered essential for the engineering development of the crucial AFBC process control scheme. This control scheme must delicately balance steam production and the inherent AFBC capacity to limit pollutants over a wide range of changes in load demand during any 24-hour period. The pilot plant is equipped with the most sophisticated computerized control systems available to enhance our engineering knowledge of the complex relationships of all operating variables that influence steam production and environmental control. The pilot plant is also necessary to develop, test, evaluate, and compare large-scale auxiliary components and variations in AFBC boiler configurations to facilitate optimum selection of components for a utility-scale AFBC boiler.

The pilot plant is equipped with several alternate process and equipment configurations. These systems are being used to develop a data base for the 160-MW(e) AFBC Demonstration Plant. Additionally, an excellent opportunity exists to eventually use this pilot plant test facility to establish a data base to compare a wide range of fossil fuel grades, such as lignites, coal-cleaning plant "rejects," and other lower grade fuels, to enable the design scaleup and use of these fuels in an AFBC utility boiler. This fuel diversification potential could markedly improve the Nation's chances of achieving energy independence.

The 20-MW(e) AFBC Pilot Plant is complete and fully operational. Since the first coal fire in May 1982, the unit has accomplished over 5,000 hours of testing with high-sulfur Kentucky coal. The AFBC boiler has operated exceptionally well, and there have been no significant AFBC technology-related problems, such as erosion of the tubes in the fluidized bed. Process performance has also been encouraging. The AFBC process can achieve in excess of 90-percent sulfur removal with a 4.2-percent-sulfur coal. It can also achieve a combustion efficiency of greater than 97 percent within an economical viable range of operating parameters. Additionally, the nitrous oxide emissions are substantially lower than the New Source Performance Standards and fall consistently in the ranges referenced for low nitrous oxide burner performance.

## 160-MW(e) AFBC Demonstration Plant Project

In September 1979, preliminary designs leading to preliminary cost estimates for a 200-MW(e) AFBC demonstration plant were initiated by contracts with Babcock & Wilcox, Combustion Engineering, and Babcock Contractors, Incorporated. For each of the designs, TVA performed plant layouts and balance-of-plant designs and prepared a preliminary draft Environmental Impact Statement (EIS). The preliminary designs were refinements of the earlier conceptual designs. Combustion Engineering, in conjunction with Lurgi-Chemie, also prepared a conceptual design of a 200-MW(e) circulating fluidized bed combustion demonstration plant. The work of the three boiler manufacturers was completed in January 1981. TVA's evaluations of these designs, plant cost estimates, schedule, and a preliminary boiler specification were also completed in 1981.

In late 1980, TVA considered the possibility of pursuing retrofit or add-on options because of load forecasts, funding availability, and regulatory requirements rather than building a standalone plant for the demonstration project. A retrofit configuration involves dismantling an existing boiler and replacing it with a new boiler in the same powerhouse; whereas, an add-on consists of a new boiler and boiler building built adjacent to the existing one. A standalone plant offers greater flexibility, but it has since been shown that the add-on option offers the greatest benefit-to-cost ratio. TVA has prepared a preliminary cost estimate (±30 percent accuracy) and conceptual design for 160-MW(e) retrofit and add-on units at Shawnee unit 10.

TVA has also performed brief studies and cost analyses wherein tailings from coal-washing facilities were used as a "free" fuel for AFBC steam generators. As a result of these studies, it had been determined that a boiler designed for firing coal-wash tailings would not likely be cost effective in an AFBC plant for the TVA system. Since there are also no significant technical advantages for using coal-wash tailings in an AFBC demonstration, TVA has no reason to build such a plant, because the additional power is not needed.

Based upon these studies, it was determined that the add-on approach could adequately demonstrate the technology in a cost-effective manner. Presently, TVA, Duke Power Company, the Commonwealth of Kentucky, and EPRI (the Principals) are working on a preliminary design and ±10 percent cost estimate for a 160-MW(e) add-on unit at Shawnee unit 10.

Also based on these studies, TVA has concluded that the next major step, a utility-scale demonstration facility, can be accomplished by replacing an existing pulverized-coal-fired boiler with an AFBC boiler. This approach will accomplish the goals of demonstrating the essential elements of the technology at a significantly lower cost than a new standalone facility.

To demonstrate the technology, an AFBC boiler would be constructed beside an existing unit at the plant as a replacement for the existing boiler. The AFBC boiler would be capable of generating approximately 160 MW(e) of electric power and would make maximum use of the existing turbogenerator set and other associated equipment. The design fuel for the demonstration is high-sulfur Illinois basin coal, as typified by Kentucky number 9. However, fuel flexibility will be considered with testing of alternate fuels during the test program. The preliminary cost estimate for the design, construction, and startup of the AFBC demonstration at Shawnee is $200 million. It is anticipated that a 3- to 4-year test and demonstration period would cost approximately $20 million.

The schedule as presently proposed allows an adequate amount of time to evaluate the pilot plant test results prior to freezing boiler designs. On this schedule, detailed design and erection of the facility will begin in 1984 and will be completed by mid-1989. Operational testing, producing power for TVA's grid, would begin in 1989. This timetable provides the electric power industry with the option of selecting an AFBC coal-fired plant in the early 1990s to provide added or replacement power to their grid in the mid-to-late-1990s.

A total of $30 million in deferred appropriations ($15 million in FY 1985 and $15 million in FY 1986) for TVA through the Department of Energy for Federal participation in the TVA 160-MW AFBC Demonstration Plant has been approved by the U.S. Congress. These funds are for the construction of the facility.

The Principals have committed a total of $135 million to the 160-MW(e) AFBC Demonstration Plant project. Kentucky has committed $10 million from their demonstration trust fund, Duke Power has committed $10 million, EPRI has committed $75 million, and TVA has committed $40 million. TVA's contribution will come from its self-financed power system, rather than from appropriations. In addition to this $40 million, TVA is providing a site, turbogenerator, baghouse, chimney, and coal-handling equipment, as well as other equipment. Also, $7.9 million has been spent on previous AFBC Demonstration Plant activities, which will be of benefit to this project. Of this amount, TVA has contributed $6.9 million in power funds, and DOE has contributed $1 million.

Remaining funds are now being sought from other utilities, foreign countries, State governments, coal companies, railroads, boiler manufacturers, and others. We have received indications of the intent to join in financial participation in excess of $25 million from a number of these sources and expect to get the remaining required funds in the near future.

Supporting Research and Development

TVA, EPRI, the boiler manufacturers, and others have identified a number of technical areas that are critical to the development of AFBC technology. Major areas identified are coal feeding, boiler construction materials, boiler control recycling of fly ash, and handling and disposing of by-products. To address these areas, TVA has undertaken a substantial number of research and development projects over the last several years. In fact, TVA has undertaken more than 50 research and development assessments and support tasks at a cost of more than $7.6 million. Of this amount, TVA provided $7.0 million in power funds and $0.6 million in appropriated funds. TVA was responsible for conducting the work or technically monitoring the work of contractors for the following programs:

- TVA designed, built, and operated a coal-feed test facility at the Watts Bar Steam Plant to evaluate the effectiveness of the Fuller-Kinyon feed pump and 3:1 and 24:1 feed-line splitters as well as to evaluate the effects of coal/limestone surface moisture.

- The Oak Ridge National Laboratory (ORNL) performed many experiments and studies in fluidization, material corrosion, coal/limestone feeding and conveying, fluidized combustion, and modeling.

- TVA, the National Coal Board, and EPRI participated in coal/limestone burn tests and boiler tube material evaluations at Leatherhead, England.

- General Atomic performed recycle tests.

- The University of Tennessee performed tests of coal-feed nozzles, air distributor plates, and alternate feed concepts and performed studies of boiling heat transfer and 2-phase fluid flow in tube bends.

- TVA and Jaycor jointly prepared a transient mathematical model of the pilot plant.

- ORNL and TVA jointly prepared a steady-state process model for the AFBC process.

- The Massachusetts Institute of Technology performed various fundamental fluidized bed combustion studies and tests.

- Several other tests were conducted at facilities, such as Battelle Memorial Institute, FluiDyne, Kentucky Institute for Mining and Minerals Research, and others.

- TVA obtained numerous environmental permits, licenses, and clearances in support of the pilot plant. In addition, a draft EIS, which incorporated draft Prevention of Significant Deterioration and National Pollutant Discharge Elimination System Permit applications, was prepared.

TVA has been interested in fluidized bed combustion technology since 1975 and consequently has developed a broad base of experience. A total of 445 man-years of experience is culminated in 125 design engineering, development engineering, operations, and technical management personnel. Many training courses, seminars, and conferences have been attended by people assigned to AFBC projects.

From TVA's viewpoint, AFBC is an important and viable technology which can significantly benefit the Nation, and it deserves continued Federal support to ensure that its goals are achieved. I appreciate the opportunity to present our program and views. I would be pleased to answer any questions this committee has. Thank you.

## DR. MICHAEL D. HIGH

Dr. Michael D. High is a native of Colorado and a 1960 aeronautical engineering graduate from the University of Colorado. He also holds a master's degree from the University of Oklahoma in the same field. Dr. High earned his doctorate from the University of Oklahoma in 1967 while serving on the faculty there. He is a registered professional engineer with over 20 years of industrial and academic experience. He came to the Tennessee Valley Authority in 1979 from ARO, Inc., of Tullahoma, Tennessee, where he held a number of supervisory and management positions.

He is presently Director of the Division of Energy Demonstrations and Technology with the Office of Power and serves as a member of the Office of Power Planning Committee. His principal responsibilities involve management and coordination of TVA's power supply and end-use research, development, and demonstration activities. Among these activities are technology developments in effluent control, power plant performance and reliability, advanced electric generation systems, atmospheric fluidized bed combustion for electric utilities, electric vehicles, waste heat utilization, innovative conservation measures, and efficient electric end-use applications.

Dr. High has served on several advisory committees for the Electric Power Research Institute and was elected to the Research Advisory Committee, which sets research policy for the institute in 1984.

He is a member of the Board of Directors for the Electric Vehicle Development Corporation.

Mr. **Boucher**. We will reserve our questions until all the witnesses have made their statements. Thank you very much, Dr. High.

Dr. Wolfe, we will be glad to hear from you.

## STATEMENT OF DR. RICHARD D. WOLFE, VICE PRESIDENT, RESEARCH AND DEVELOPMENT, UNITED COAL CO.

Dr. **Wolfe**. Thank you, Congressman Boucher. I am certainly pleased to be able to appear before this subcommittee and talk about a subject that is certainly dear to my heart, and that is the greater use of coal and the advancement of new coal technologies. My views may or may not be different from others that you hear from today, but certainly they are views that come from someone who has been born and raised in the coal fields, and certainly my views have been molded by the heritage that I have.

I come here for one particular purpose, and that is to have an impact on this coal budget and talk about the new technologies that can help the coal industry and help this country start using more coal. If I fail in that mission and if we fail in this mission today to change this budget, I think we as a Nation lose. So I am indeed motivated by trying to have some impact within this system that we have here in this country, to try to set this course straight with our energy development.

I do believe it is important that we establish what the picture of the energy perspective is today. I definitely believe that if we are going to have a strong national defense, and there is so much money being put into the national defense, if we do not have resources captive to our own national boundaries, we are not going to have a strong defense. I don't care how many jet planes or how many ships we build, if we have to rely on imported oil to run those ships, we do not have a strong national defense.

Certainly, our foreign policy has been affected today by the Mideast influence and our demand for a need for oil from that country. We are even importing more oil today than we did a year ago and the year before that. I think we as a country need to establish that imported oil is our national villain. I think that should be the motivation for which we should structure these coal R&D programs. We should structure coal R&D programs to reduce oil and start using coal, and the technology should be structured toward that.

I do not think that we should hold this coal in reserve for those rainy days that are yet to come. I think we desperately need to use those coal resources today, and reduce our imported oil. I think we can do that. We can make our economy strong, we can create a self-esteem and respect. We can increase employment and put this country back to work.

Let's not forget that imported oil is our villain, and that is where we should be motivated toward national energy independence.

That reflects back into the coal R&D program, and what is disturbing to me is when I look at this fiscal year 1985 program, it has been established, I see a drastic cut in the coal programs while at the same time, the DOE is putting millions and millions of dollars in the nuclear program. In fact, the coal program is $178 million proposed; the nuclear program is $618 million for R&D $350 million for nuclear waste technology, $100 million for uranium enrichment, and really untold millions in the defense program.

You are talking about a misalignment, in my opinion, for these funds. I do not believe that the DOE should increase its funds. I certainly believe that we ought to cut back on Federal spending. I just think it is time that we realign our energy development funds consistent with our national needs. Certainly, this is where coal programs should be funded. In fact, I think that the coal and the nuclear programs probably should be reversed in funding levels, and it would best serve this country's needs to do that.

Let me talk about the coal R&D program, and tell you about some of the exciting things that are developing in the coal industry. Certainly, I want to see coal being used more than it is today, and therefore I am motivated by new markets, not trying to do the same old thing better, but also trying to develop some new markets with a greater use for coal as a replacement for oil.

Basically, the technology and the coal industry is really prone and stands ready to implement this technology. I believe that the coal R&D programs, funded by the Federal Government, have receive tremendous recognition within the coal industry and the industry is now starting to implement some of those technologies. So, Federal dollars spent in coal research and development go a long way to developing these new technologies, and the coal industry is starting to take advantage of those technologies, but it does need the dollars funded by the Federal Government to be the catalyst for getting this coal used, and also the technical talent associated with it.

For example, United Coal Co. is one of the largest coal companies in Virginia and one of the largest research-oriented coal companies. Just this past week, we have announced the establishment of a new research center, our coal research center, in Virginia to look at making coal/water-mixture fuels and trying to develop a coal/water-mixture fuel and a coal-slurry fuel that can replace oil being burned in boilers.

We have now started that plant. We are commercially making quantities now for testing in local markets. We are doing some testing in the local industrial markets, and we are working with some major utilities now to start burning this coal.

The Federal dollars that were spent over the last several years in developing this technology for coal/water-mixture fuels is now starting to see commercial companies looking at that particular technology as a business. There is an excellent example, and I don't think you can see that kind of example in the nuclear program. So, I do believe that the Federal dollars spent on coal research goes a long way to helping get the commercial use of coal.

The second item I want to talk about is the technology for coal cleaning. I have brought a sample here for the committee to talk about some of the new technologies in coal cleaning. Again, that was stimulated by the Government R&D. Here is some coal that has been cleaned to less than .9 percent ash and .6 percent sulfur. This was not a far out technology. This technology that was used to achieve this type of cleaning could be commercialized within a few years.

You have to have the market. Again, why do you need to clean coal so low? Because if you can put this coal into a liquid form and it can be used in diesel locomotive engines or marine engines used by the Navy, we can indeed create a new market of 70- to 100-million-additional tons of coal. That is what motivates us. That is what motivates, I think, this country to reduce the amount of oil that we are using.

I am very excited about these technologies, but I cannot reiterate enough the benefit of Government R&D in these areas.

A third thing is about the industry being ready to benefit from this technology. I do not believe that the coal industry is a mature industry, as some opponents would have you believe. It certainly needs some help. It certainly needs the technology that the Government funding can provide.

With regard to the DOE budget, I really think that we need to increase that DOE budget by some $96 million. I don't think we should ask for the world, but I do think that a 17-percent increase over last year's budget is certainly reasonable, but I do believe we ought to establish some new programs in the DOE program.

The five programs that I have outlined which I think are directly directed toward reducing the imported oil use is in the area of some new coal-slurry fuel form development. There are tremendous gains to being able to not necessarily just make hydrogenation or liquefaction of coal, but to use some other techniques that are being developed to make a liquid coal product that can be burned in these new gas turbines instead of using natural gas or oil or to start being burned in diesel locomotive engines.

I also think there should be a program directly, specifically funding toward diesel locomotive applications of coal. The railroads in this country, particularly the two large railroads located in Virginia used over $1 billion in fuel last year. One particular railroad used $500 million for diesel fuel to haul coal back and forth. Now, we lost that market years ago to the locomotive industry, but it is time we got it back. At $1 a gallon for diesel fuel, that equates to about $200 per ton. Let me assure you that we can spend an awful lot of money and we can clean an awful lot of ash and sulfur out of coal for $100 a ton.

So the technology exists and the economics exist. I think we need to have some Government programs to help in that area.

The third area is in acid rain reduction. I definitely believe there ought to be a specific program directed toward that and developing the technology in which we can clean the coal from the sulfur and also clean it while it is being combusted.

The fourth area is in coal waste recovery. One of the major waste products in the country today is coal waste from coal preparation plants. There is a tremendous energy resource there that is not being used. The technology just does exist to get all that carbon material out of the waste.

It is being disposed of by millions and millions of tons throughout the Appalachian region. There is a tremendous resource and it should be funded. Initial efforts in technology should be funded by the Federal Government. The benefits to be gained from such a program are tremendous in resource recovery, so it should not be hidden within the system. There is less than $2 million out of the whole DOE program spent on waste management today. That program certainly should be funded greatly.

The fifth area is in coal-fired turbines. Today, turbines are used throughout the utility industry and they are fired by natural gas and oil. There is technology available now when you clean the coal to very low levels that you can burn this coal in turbines that have been redesigned so that they can withstand the type of corrosion aspects.

So those are five new programs that I would like to recommend. I think that $96 million would be well spent for the benefits to be gained throughout the coal industry by putting some emphasis in this area.

In conclusion, I definitely believe that it is time that we here in Washington, and certainly you as a Congressman and others here have an obligation to this country to really see that our energy alignment is consistent with our national needs. I think we cannot delay it. It needs initiative now. I think if we do not take initiative now to change this budget, we are going to get deeper and deeper with the imported oil, and our national democracy is at stake.

Thank you.

[The prepared statement of Dr. Wolfe follows:]

# INVITED TESTIMONY BEFORE THE U.S. HOUSE OF REPRESENTATIVES SUBCOMITTEE ON ENERGY DEVELOPMENT AND APPLICATION

MARCH 6, 1984

Dr. Richard A. Wolfe
Executive Vice President
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Mr. Chairman and distinguished members of the subcommittee, I would like to introduce myself to the committee. I am Dick Wolfe, Executive Vice President of UCC Research Corporation, The Research Division of United Coal Company. It is my pleasure to have this opportunity to address this subcommittee.

During the course of these hearings, you will have the opportunity to listen and evaluate a broad range of views presented to you by many different people. My view, which may or may not be different from what you have heard, but it will be a view that comes from a person who was born and raised in the coal fields. A view which was shaped by experiencing the economic plights which the coal fields have had to endure. A view that has been tempered by witnessing, the suffering from the dreaded Black Lung disease which fell upon my own father, and eventually took his life. A view from one who had to leave the coal fields to seek employment as a chemical engineer because there were no jobs for such people. A view from one who has worked in private business and in the upper levels of the Federal Government. In short, gentlemen, I present to you a perspective that has been shaped, molded, and tempered by my heritage and experience associated with the coal industry.

I am here today to give you my thoughts and the thoughts of others who are aware of the exciting technological advancements that are now being developed within the coal industry. I am also here to express my concern with the Federal budget proposal as it pertains to Coal Technology development. I, along with my colleagues who are involved in coal research and development programs, are quite upset and concerned over the current budget reductions in the coal program and I am here to address those concerns.

Before discussing the specific needs of the coal R&D program, I feel compelled to give you a brief perspective of the U.S. Energy picture.

## U.S. Energy Perspective

One thing is for certain, it is time that we in this country stop playing politics with our national energy needs and programs. No matter how many jet planes, new ships, or other sophisticated defense projects we build, if we don't have fuel captive to our own natural resources to run them, we will not have a strong national defense. Already, our foreign policy in the Middle-East is being influenced by our needs for oil from that region. We are currently importing more oil today than this time last year or the year before. We must not "kid ourself" that we have indeed cut-back on the importation of oil due to developing our own supplies. No, our recent recession has cut back the demand and as our economic recovers, so will our demand for imported oil. Gentlemen, if we can reduce the $70 billion or so being paid out of our country for imported oil and develop our own liquid fossil resources here at home, we can then solve our own economic problems. By developing our own coal resources to meet the liquid energy needs of our country we can have the greatest impact of any single measure on improved U.S. employment, greater self-esteem, national security, and reduction of the national deficit. "IMPORTED OIL IS OUR NATIONAL VILLAIN."

Coal is our most abundant natural resource. We have more coal energy equivalent than all the oil in the Middle-East. We must not "hord" this coal resource for a rainy day. Those rainy days are now. New technology development of energy sources not yet dreamed of will be developed in the centuries to come to supply our energy needs. We just cannot afford to lose the democracy we know, in the meantime, by continuing to increase our dependency upon the fragile imported oil supply.

## THE DOE FY-1985 CONGRESSIONAL BUDGET REQUEST

After a careful review of the DOE FY-1985 Budget Request, the most disturbing observation to me is the proposed cut-back in the coal R&D programs even beyond the reduced levels of FY-1984, while at the same time increasing the nuclear energy R&D programs. The Coal R&D Program is to be funded at a level of $178 million, while the nuclear program is to be funded at a level of $618 million for R&D, $350 million for the nuclear waste fund technology, $100 million for Uranium Enrichment and untold millions in the Atomic Energy Defense Activities that is directly related to nuclear energy development. Gentlemen, this misalignment of taxpayers funds is not consistent with the energy needs of this country and I propose the levels of funding between the nuclear and coal programs would better serve the energy and national security needs of this country by simply being reversed.

Now hopefully having the wisdom to recognize those things I cannot change and those things, I may have some influence upon, I want to address specifically the needs of the coal R&D programs and recommend some new programs that can contribute to improvements in that program.

## COAL RESEARCH AND DEVELOPMENT PROGRAM

Gentlemen, first let me say that the coal industry is not a mature industry as some opponents would have you to believe. But the potential is there with the use of developing technologies to convert coal into liquid forms that can literally free us from the bondage we face with the importation of foreign oil. Not only can we free ourselves from this villain, but we can do it much cheaper than at the current OPEC price. And we can use coal, clean the coal of its sulfur and impurities to meet the current environmental guidelines. The technical feasibility exist in many cases, but needing only to develop the technology to the point of commercial application. These changes will transform the image that many perceive of the coal industry. We are not simply talking about an old dog with a new face, we are talking about a new industry which could account for over 150 million tons of new coal production and use in this country. The government sponsored R&D programs, as "meager" as they have been, has provided the technology catalyst that now brings new hope into an old resource.

The best advice I can give in structuring the coal R&D program is to first define the energy market needs and let them serve to define the priority R&D programming. Certainly, the most obvious big market needs is to first develop those technologies to replace oil being burned in utility and industrial boilers, and secondly, to replace diesel oil being used in Marine, Naval and locomotive engines. This market alone is well over 85-90 million tons of new coal utilization. However, to achieve this market penetration, expanded new technology development is needed. In this regard, increased R&D funds should be provided towards developing the technology to first clean the coal of its impurities to the market levels required, secondly, convert the coal into a slurry form with increased emphasis on new fuel form developments, and third, develop the technology to accelerate the use of new liquid coal in power plants, gas turbines, and locomotive and marine diesel engines. The technology funding in these areas can have a major impact in coal's utilization in a short time.

With regard to the coal energy's R&D budget breakdown, the following adjustments are recommended as specified in Table 1.

The program changes recommended are directed toward developing new product forms for coal that can develop a coal based fuel that can replace oil and increase coal's utilization. For example, the new coal fuel form development program should include technology development to convert coal into a liquid fuel of comparable quality to oil in ash and sulfur for use as a direct substitute for oil in the mobile and industrial markets. The mobile market includes transportation fuels for Diesel applications is a tremendously important new market for coal. The new program for Diesel application would be directed toward building and modifying the engines to use the newly developed coal based fuel. The increased funding recommended for the coal preparation projects would be directed toward developing technology to clean the coal of its sulfur and ash to a level comparable with diesel oil. This cleaning technology is developing rapidly and already some small laboratory test show coal can be cleaned to as low as 0.1 percent ash, which is indeed equivalent to some diesel fuels.

## TABLE 1
## FOSSIL ENERGY BUDGET BREAKDOWN

| | (BUDGET AUTHORITY IN THOUSANDS OF DOLLARS) | | | |
|---|---|---|---|---|
| | FY 1984 ESTIMATE | FY 1985 REQUEST | WOLFE'S RECOMMENDATION | AMOUNT CHANGE |
| COAL LIQUEFACTION.............. | 28,900 | 13,900 | 30,000 | +16,000 |
| SURFACE COAL GASIFICATION...... | 36,790 | 15,000 | 20,000 | + 5,000 |
| UNDERGROUND COAL GASIFICATION.. | 6,000 | 5,850 | 5,850 | 0 |
| ADVANCED RESEARCH & TECHNOLOGY DEVELOPMENT.................. | 39,250 | 40,267 | 40,267 | 0 |
| CONTROL TECHNOLOGY & COAL PREPARATION.................. | 26,000 | 32,150 | 45,000 | +12,850 |
| HEAT ENGINES & HEAT RECOVERY. | 6,500 | 7,650 | 10,000 | + 2,350 |
| COMBUSTION SYSTEMS........... | 18,200 | 31,675 | 20,000 | -11,675 |
| FUEL CELLS................... | 42,600 | 13,700 | 13,700 | 0 |
| MAGNETOHYDRODYNAMICS......... | 30,000 | 17,800 | 17,800 | 0 |
| SUBTOTAL, COAL............... | 234,240 | 177,992 | 202,617 | |
| NEW PROGRAM'S RECOMMENDED | | | | |
| NEW COAL FUEL FORM DEVELOPMENT | | 0 | 15,000 | +15,000 |
| DIESEL LOCOMOTIVE/MARINE APPLICATION................. | | 0 | 25,000 | +25,000 |
| ACID RAIN REDUCTION TECHNOLOGY | | 0 | 10,000 | +10,000 |
| COAL WASTE RESOURCE RECOVERY. | | 0 | 12,000 | +12,000 |
| COAL FIRED TURBINE SYSTEM... | | 0 | 10,000 | +10,000 |
| RECOMMENDED COAL PROGRAM | | | 274,617 | +96,625 |

## CONCLUSION

I believe the interest of this nation and the taxpayers investment can best be served by increasing the coal R&D budget by at least the 96 million proposed. This would be only a 17 percent increase over FY-84, and certainly a small increase when compared to the national benefits to be obtained. I would propose that this funding be provided by direct reductions in the $618 million nuclear R&D program. Again, the nuclear R&D program is "criminally" over-funded and has been for years when compared to the national benefits that can be gained by increased funding in the coal R&D program.

The potential for breakthroughs in coal technology is greater than with any other single energy resource. Since so little technology or government money has been spent in coal R&D compared to nuclear energy development, numerous technology breakthroughs still remain to be made that can use coal in those new markets to replace oil. And in closing, let me say that the coal industry as exemplified by United Coal Company's commitment to research, stands ready to implement the technology once the technical and economic feasibility is established. Government funding is important as the catalyst to minimize some of the initial high risk. Several examples already exist that show how rapid and proned the industry is to accelerate the commercialization of good technology developed by the government: coal-water mixture fuel is now being commercialized by a number of companies, including United Coal Company and converting coal into methonal for gasoline blending stock is now being commercialized by Tennessee Eastman Company using good Virginia coal.

In any future government funding program, great effort should be made to encourage those companies and industries who will benefit the most by commercialization to participate in the Research and Development. In this way, once the technology is developed, the technology transfer has already been achieved. Simply, special efforts and encouragements should be made by the government agencies to not develop the technology all in-house as is now being done at some energy centers, but to involve the coal industry more directly in the technology development.

Thank you for this opportunity to present my analysis of the federal energy budget. As national leaders, you must find a way to set a course to obtain national energy independence. The course is long and will, undoubtedly, span several Administrations with different political bias. However, we must stay on course if this nation is to achieve our energy objectives or we will truly repeat Roman history of "fiddling while Rome burns."

## RICHARD A. WOLFE, Ph.D.

Executive Vice President - UCC Research Corporation
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Bristol, Virginia

Corporate Vice President - Research & Development
United Coal Company
P.O. Box 1280
Bristol, Virginia

### EDUCATION:

B.S. Chemical Engineering - Virginia Polytechnic Institute - 1961

M.S. & Ph.D. Engineering - University of Cincinnati - 1966, 1972

### EXPERIENCE SUMMARY:

| | |
|---|---|
| 1983 - Present: | Executive Vice President of the newly established UCC Research Corporation. This new corporation serves as the Research Division of United Coal Company. Responsibilities include providing overall management and technical direction for this newly established profit center of United Coal Company. |
| 1979 - Present: | Vice President of United Coal Company in Bristol, Virginia. Responsible for corporate-wide Research and Development. These responsibilities range from improved coal mining techniques to improved coal preparation and conversion of coal to synthetic fuels. Serves as corporate expert and company representative on energy development. |
| 1977 - 1979: | Chief, Development Branch, U.S. Department of Energy, Washington, DC. Responsible for program management of one of DOE's largest development programs. Received two special DOE certificates for superior program management. |
| 1974 - 1977: | Program Manager, U.S. Energy Research and Development Administration in Washington, DC. Responsible for program management of Waste Management and Environmental Control projects. Participated as a representative to the International Energy Agency's Committee on Waste Management. Received ERDA Superior Performance Award for Program Management. |

1961 - 1974: Monsanto Research Corporation, Miamisburg Ohio. During a thirteen-year period, served in a variety of supervisory and management positions. Responsible for several major technical and environmental control programs.

HONORS - AFFILIATIONS:

Governor's appointee to the Virginia Coal and Energy Commission for Commonwealth of Virginia.

Vice Chairman of the Virginia Coal Council

1972 - Selected to Who's Who in American Men and Women in Science

Numerous publications in the field of Program Management and Engineering

Mr. BOUCHER. Thank you, Dr. Wolfe.

Dr. Roberts.

## STATEMENT OF DR. GEORGE W. ROBERTS, GENERAL MANAGER, COMMERCIAL DEVELOPMENT DIVISION PROCESS SYSTEMS GROUP, AIR PRODUCTS & CHEMICALS INC.

Dr. ROBERTS. Good morning, Mr. Chairman and members of the subcommittee. I am George Roberts of Air Products & Chemicals Inc. It is a pleasure to be with you today and to testify at these hearings.

My responsibilities at Air Products include both the development and the commercialization of new technologies. Thus, I have a unique opportunity to overview the total innovation process.

The purpose of my testimony today is to ask for continued financial support from the Department of Energy for a project that I believe has the potential to become an important national and world scale innovation, and that is the liquid phase methanol process. Specifically, I am requesting the committee to authorize an additional $5 million in DOE's fiscal year 1985 fossil energy budget, with these funds specifically earmarked for operation and support of the DOE Process Development Unit at LaPorte, TX. These funds will allow for further development of new cost effective technology for producing methanol from coal.

However, the benefits of this research will extend far beyond methanol per se. The project will produce important results that should have positive effects on the whole area of indirect coal liquefaction. Indirect coal liquefaction is an important technology for the United States because of its inherent flexibility. Indirect liquefaction has the flexibility to accommodate a wide range of coals, ranging from eastern anthracites, midwestern bituminous coals to western sub-bituminous coals, southern lignites.

It has another aspect of flexibility that is very important and that is the indirect liquefaction processes can be tailored to meet market needs. With indirect liquefaction, a spectrum of products can be produced, ranging from methanol on the one hand to diesel fuel and home heating oil on the other hand.

Before getting into the proposed authorization for operation and support of the LaPorte PDU to further develop liquid phase methanol technology, I would like to address two more general issues that are of special concern to this subcommittee. The first is the appropriate Federal role in energy research and development, and the second is the effectiveness of past Federal programs in advancing strategically important technologies. Consistent with Dr. Wolfe's testimony, I feel that coal utilization is a very strategically important national technology.

Synthetic fuels, first and foremost, are a national issue. Questions of energy availability, sourcing, and pricing are directly linked to national security and to the health and stability of the national economy. The American public is going to be the main beneficiary of a well planned Federal program in synthetic fuels. Conversely, the public is going to suffer the consequences if the Federal Government abdicates its rightful role in synfuels development.

Recent events in the Arabian Gulf serve to highlight these remarks.

It is essential that the Government maintain a long term, aggressive program to support synthetic fuels technology development. Further, it is particularly important that the continuity and the stability of this program be sustained, regardless of whatever temporary surpluses we might have in the availability of crude oil on the international market.

Private industry has a legitimate role to play in the overall synthetic fuels effort as an instrument of national policy in the execution of technical and commercial programs. However, the development of a synfuels industry faces a truly awesome combination of risks: Financial risks, market risks, technical risks, environmental risks, and regulatory risks. These combined risks are much too much for the private sector to bear alone.

There are many smaller, innovative, technologically competent companies that could contribute substantially to the technical base for a commercial synfuels industry. However, these companies will be effectively excluded unless financial support from the Federal Government makes it possible for them to participate. The Nation will benefit if the Federal Government's policy encourages broad private participation in the synfuels industry.

To put the present synfuels effort in context, let's look a bit at the effectiveness of past Federal R&D programs. History certainly contains a number of examples in which the Federal Government has successfully supported the development of a new technology that was ultimately utilized to meet a critical national need. Some of these technologies were eventually spun off into the private sector where they produced substantial additional benefits to the Nation's economy.

For example, the basic aerodynamics research conducted by the NACA, the predecessor agency to NASA, started in the early 1920's, and this research provided the foundation for the design and construction of military aircraft during World War II. In 1943, then Secretary of the Navy Frank Knox offered the following testimonial:

> The Navy's famous fighters—the Corsair, the Wildcat, and Hellcat—are possible only because they were based on fundamentals developed by the NACA. The great sea victories that have broken Japan's expanding grip in the Pacific would not have been possible without the contributions of the NACA.

On the other hand, there are examples of the failure of the Government to establish a critical technology, where that failure has impaired the country's ability to respond to national emergencies. An excellent example is the absence of a federally perceived need for synthetic rubber prior to World War II.

Unfortunately, my comments to this subcommittee 2 years ago concerning the synthetic rubber analogy remain as true today as they were then. Several U.S. companies were involved in the research on synthetic rubber in the early and middle 1930's. However, these research programs were gradually terminated because the anticipated costs of synthetic rubber were too high to compete with natural rubber. Furthermore, the quality of the synthetic rubber that was being produced in these early research efforts was judged to be inferior to the quality of natural rubber. There was little commercial incentive to solve those problems.

Those two arguments, cost and quality, have a very familiar ring. We hear the same things being said about synthetic fuels today. Consequently, when the Japanese swept through Malaysia and Indonesia in 1941, totally cutting off our supplies of natural rubber, the country had essentially no capacity for producing synthetic rubber. True, during the next several years, a crash program was put in place to develop a synthetic rubber industry, and in 1944, when the war was almost over, substantial production rates were being achieved.

The analogy between synthetic rubber and synthetic fuels is very strong and must be obvious to all members of this subcommittee.

I would like to turn now specifically to the liquid phase methanol program and the LaPorte process development unit. In recent years, the Government has made a strong commitment to research aimed at converting our Nation's abundant coal resources into liquid fuels that can be substituted for products derived from imported petroleum. Certainly, in this respect, my opinions concerning the Government role and the Government program coincide with Dr. Wolfe's.

The creation of innovative technologies that can effectively convert a wide range of our domestic coals into liquid fuels is important to national security and to the national economy. The LaPorte PDU and the liquid phase methanol program is highly consistent with this objective.

Methanol, the end product of the technology, holds promise as a clean, premium fuel, an environmentally benign fuel, in a variety of potential applications. It finds use in the transportation fuel markets, it finds use as a feedstock for octane enhancers, and it finds use as a promising fuel for electric power generation. Through these uses, methanol from domestic coal can become an important substitute for imported petroleum.

The liquid phase methanol technology that is currently under development has the potential to be a more efficient, lower cost means of producing methanol from coal than current commercial processes which must be licensed from foreign firms and which were designed to produce methanol from natural gas, itself a premium fuel. Our research work to date has begun to confirm our belief that liquid phase methanol technology is particularly advantageous when the starting raw material is coal. Tangible progress has been made in the development of the liquid phase methanol process, and this potential must now be verified and expanded through additional research.

The proposed continued work contains a very strong element of generic technology development that will be applicable to a host of problems in coal liquefaction. In particular, the project involves fundamental research on the behavior of three-phase reactors, where this research is being done in a facility that is large enough to permit the study of important engineering variables which influence process performance.

The LaPorte facility presents the country with a unique opportunity to perform cost effective research to obtain the data and develop the technology necessary for the deployment of a synthetic fuels industry during the next period of national need.

I think there are a number of reasons why the Government should continue to support this key project in DOE's indirect coal liquefaction program:

One, indirect liquefaction is an innovative, promising, flexible way to convert the Nation's abundant coal resources into clean, liquid fuels that can substitute for imported petroleum.

Two, the liquid phase methanol project and the LaPorte PDU are basic to DOE's overall program in indirect coal liquefaction. This program contains a large component of generic research that is going to be broadly applicable.

Three, methanol, the end product of the technology, holds promise as a clean premium fuel in a variety of applications.

Four, the work that has been done to date is encouraging. It shows that liquid phase methanol has the potential to be a more efficient, lower cost route than currently available technologies.

Five, the proposed project is structured in a way that makes sense from both a Government and a private sector viewpoint. The broad private participation in the liquid phase methanol program ensures that this research, if it eventually proves to be successful, will not languish for lack of interest or capability.

Six, the high risk, long-term nature of the project limits industry's ability to undertake the research without government participation.

Mr. Chairman and members of the subcommittee, thank you for your attention and for the opportunity to testify. At the end of the session, I also will be happy to answer questions.

[The prepared statement of Dr. Roberts follows:]

Dr. George W. Roberts
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Process Systems Group
Air Products and Chemicals, Inc.
Allentown, Pennsylvania 18105

House Committee on Science and Technology
Subcommittee on Energy Development and Applications

MARCH 6, 1984

Good morning, Mr. Chairman and Members of the Subcommittee. I am George Roberts of Air Products and Chemicals, Inc. (Air Products). It is a pleasure to be with you today, and I appreciate the opportunity to testify at these hearings.

My responsibilities at Air Products include both the development and commercialization of new technologies, thus providing a unique opportunity to impact on the total innovation process. The purpose of my testimony is to ask for continued financial support from the Department of Energy (DOE) for a project that has the potential to become an important national- and world-scale innovation, namely Liquid-Phase Methanol (LPMeOH). Specifically, I request the committee to authorize an additional $5.0 million in the DOE's FY 1985 fossil energy budget, with these funds specifically earmarked for operation and support of the DOE Process Development Unit (PDU) at LaPorte, Texas. These funds will allow further development of new cost-effective technology for producing methanol from coal. However, the benefits of this research project will extend far beyond methanol per se. The project will produce important results that should have positive effects on the whole area of indirect coal liquefaction, including the Liquid Phase Fischer-Tropsch technology presently being developed to improve our ability to produce diesel fuel from coal.

Before discussing the proposed authorization for operation and support of the LaPorte PDU to further develop LPMeOH technology, I would like to address two more general issues that are of special concern to this subcommittee:

- The appropriate Federal role in energy research and development, and;
- The effectiveness of past Federal programs in advancing strategically important technologies.

My comments on the first of these issues will concern synthetic fuels R&D.

## The Federal Role in Synfuels R&D

Synthetic fuels remain, first and foremost, a national issue. Questions of energy availability, sourcing, and pricing are directly linked to national security and to the health and stability of the national economy. The American public will be the main beneficiary of a well-planned and well-executed federal program in synthetic fuels. Conversely, the American public will suffer the consequences if the federal government abdicates its rightful role in synfuels development. Recent events in the Arabian Gulf remind us of the necessity to reduce our dependence on foreign crude oil. Developing the innovative technology required to efficiently apply our nation's vast coal resource to this need is a key part of the total solution. Toward this end, it is essential that the Federal Government maintain a long-term, aggressive program to support synthetic fuels technology development. Further, it is particularly important that the continuity and stability of such a program be sustained, regardless of temporary surpluses of crude oil on the international market. To do otherwise would hand over control of our synfuels technology program to the oil exporting nations, and would preclude an efficient and timely buildup of domestic synfuels capacity when future needs require it.

Unfortunately, since World War II, research on synthetic fuels in the United States has undergone several cycles of emphasis and de-emphasis. These cycles have been brought about by inconsistencies in federal policy and funding, and have been very damaging to the development of synfuels technology. It is important that this pattern not be repeated.

Private industry has a legitimate role to play in the overall synthetic fuels effort, as a means for executing technical and commercial programs. However, the development of a synfuels industry faces an awesome combination of risks - financial, market, technical, environmental, and regulatory. These combined risks are too much for the private sector to bear alone. Therefore, private industry must look to the government for the financial support required to mitigate these uncertainties. Without substantial government financial support for synfuels R&D, a commercial synfuels industry is very unlikely to develop within the time frame of national need. Moreover, any industry that did emerge would have a very limited number of participants, most likely involving only a handful of the largest of today's energy companies. There are many smaller, innovative, technologically competent companies that could contribute substantially to the technical base for a commercial synfuels industry. However, these companies will be excluded unless sufficient government support makes it possible for them to participate. The nation will benefit if the federal government's policy encourages broad private participation in the synfuels industry.

While the timing of the requirement for a coal-based synthetic fuels industry is a subject for considerable debate, it cannot be disputed that the country will ultimately need to draw on its vast coal reserves to satisfy its energy requirements. At that time, technology will be necessary to convert coal, efficiently and in an environmentally benign manner, into the liquid and gaseous fuels required by the country's distribution and utilization infrastructure. Government-supported coal conversion R&D programs that are performed by universities, industry, and government laboratories must provide the data base that is needed to ensure that various technologies can be deployed once the national need materializes. Surely the benefits of accelerating the development of synthetic fuels outweigh the risks of being unprepared in the event of a third oil crisis.

Unfortunately, some critics have voiced a concern that, with its large financial involvement, the government is assuming all of the risks in synfuels development. This view fails to recognize that, in addition to capital, industry is dedicating a portion of its most valuable resource - management and skilled technical people - to the synfuels effort, in preference to other potential opportunities. Moreover, industry will take on an increasing share of the financial burden as advanced technologies are developed and proven, and as markets develop.

## Effectiveness of Past Federal R&D Programs

My comments of two years ago to this subcommittee regarding past Federal R&D programs remain as true today as they were then. History contains a number of examples in which the federal government has successfully supported the development of a new technology that was ultimately utilized to meet a critical national need. Some of these technologies were spun off into the private sector, and produced substantial additional benefits to the nation's economy. For example, the basic aerodynamics research conducted by the NACA (National Advisory Committee for Aeronautics, predecessor to NASA), starting in the early 1920's, provided the foundation for design and construction of military aircraft during World War II. In 1943, then Secretary of the Navy Frank Knox offered the following testimonial:

> "The Navy's famous fighters - the Corsair, Wildcat, and Hellcat - are possible only because they were based on fundamentals developed by the NACA. All of them use NACA wingsections, NACA cooling methods, NACA high lift devices. The great sea victories that have broken Japan's expanding grip in the Pacific would not have been possible without the contributions of the NACA."

After World War II, NACA turned its attention to jet engines, and developed the technology base from which many generations of military and commercial aircraft were developed.

Conversely, the failure of the government to establish a critical technology has occasionally impaired the country's ability to respond to national emergencies. An excellent example is the absence of a federally perceived need for synthetic rubber before World War II. Several U.S. companies were involved in research on synthetic rubber in the early 1930's. However, these research programs were gradually terminated in the middle and late 1930's because the anticipated costs of synthetic rubber were too high to compete with natural rubber. In addition, the quality of synthetic rubber products was inferior to those made from natural rubber, and there was little commercial incentive to solve these technical problems. Consequently, when the Japanese swept through Malaysia and Indonesia in 1941, totally cutting off America's sources of natural rubber, the country had essentially no capacity for producing synthetic rubber. During the next several years, a crash program to develop a domestic synthetic rubber industry began to bear fruit, such that, in 1944, when the war was almost over, substantial production rates were being achieved.

The analogy between synthetic rubber and synthetic fuels is frighteningly strong. The United States can either develop a policy that will enable a smooth transition to synthetic fuels, or settle for a last-minute, frantic approach to synfuels development, as happened with synthetic rubber. The U.S. government must take substantial initiatives to prevent history from repeating itself.

Air Products' cooperative efforts with the government date back almost to its founding in 1940. World War II created an urgent need for breathing oxygen for use in high-altitude bombing missions. Air Products responded by designing and building mobile oxygen generators to produce the gas for the government.

During the Cold War, our nation's missile and space programs required large quantities of liquid oxygen and liquid hydrogen for use as propellants. Government-sponsored research and development contracts were awarded to our company to help meet these needs. These contracts were followed by pilot plants and demonstration plants, which supplied the needs of a variety of federal programs. Subsequently, Air Products, as well as its competitors, applied this technological know-how successfully in the private sector. The tremendous growth of the commercial hydrogen business would not have been possible except as a spin-off of federally funded R&D.

Industrial oxygen is another specific example of the commercial benefits reaped from government/industry cooperative technological efforts. In 1945, oxygen cost about $1.00 per hundred cubic feet. Even though it is a very energy-intensive product, oxygen now costs only about 25 cents per hundred cubic feet. The technology developed by private industry, with the aid of substantial government funding, resulted in technological improvements and economies of scale that reduced costs and thus benefited all of society.

I can't promise that kind of cost reduction for synthetic fuels. However, I feel strongly that innovative technology for converting our nation's vast coal reserves into environmentally acceptable alternatives to imported oil is ready to be developed and demonstrated.

## Operation and Support of the LaPorte PDU (LPMeOH Technology Development)

In recent years, the U.S. government has made a strong commitment to research aimed at converting our nation's abundant coal resources into liquid fuels that can be substituted for products derived from imported petroleum. The creation of innovative technologies that can efficiently convert a wide range of domestic coals into liquid fuels is important to our national security. DOE's overall program in indirect coal liquefaction, including operation of the LaPorte PDU to develop Liquid Phase Methanol and similar technologies, is highly consistent with this objective.

By way of background, the conversion of coal to liquids, or "coal liquefaction" as it is commonly called, can be accomplished by two different types of processes -- "direct" liquefaction and "indirect" liquefaction. Direct liquefaction produces liquids by the reaction of coal with hydrogen at high temperature and pressure. Indirect liquefaction involves the gasification of coal with steam and oxygen to produce synthesis gas, a mixture of hydrogen and carbon monoxide. The synthesis gas is then reacted in the presence of a catalyst to produce liquid fuels. Depending on the catalyst used and the process conditions employed, different liquid fuels can be produced. Indirect coal liquefaction is more flexible than direct liquefaction with respect to the types of coal that can be used and the end products that can be produced, e.g., jet fuel, gasoline, diesel and methanol. However, fundamental technical improvements are essential for indirect liquefaction technology to achieve its full potential.

Historically, most of the emphasis in the coal liquefaction R&D programs supported by the United States Government has been on direct liquefaction. Indirect liquefaction technology has benefited from government support for coal gasification R&D because coal gasification is the first major step in indirect liquefaction. However, relatively speaking, only a small effort has been placed on the second major step -- the catalytic conversion of coal-derived synthesis gas into useful liquid fuels.

Recognizing the need for basic, long-range research in indirect liquefaction, DOE contracted for the design, construction and operation of a PDU at LaPorte to develop an important advanced technology for the indirect liquefaction of coal -- the LPMeOH process.

The innovative LPMeOH process was originally conceived by Chem Systems Inc. (CSI). Early development work was carried out by CSI under the sponsorship of the Electric Power Research Institute (EPRI). The existing LPMeOH program undertaken by DOE and Air Products will end midway through FY 1985. This program has included research by CSI, as a subcontractor to Air Products, at CSI's laboratories in Fairfield, New Jersey. Additional research is being carried out at the Air Products laboratories in Allentown, Pennsylvania. An existing DOE facility, originally built for Liquid Phase Methanation (LPM), was revamped and relocated from Chicago to LaPorte, Texas where it formed the basis for the recently completed PDU. Limited duration testing will be underway at the LaPorte PDU in the near future.

Methanol, the end product of LPMeOH technology, holds promise as a clean, premium fuel with a variety of potential applications. It can be used alone as a transportation fuel, or it can be blended with gasoline as an octane booster. It can also be used as a feedstock to produce MTBE (another octane booster for gasoline) or as an intermediate in the Mobil-M process for producing gasoline. Finally, methanol is a promising fuel for electric power generation, primarily as a fuel for gas turbines. By fulfilling needs in these areas, methanol from domestic coal could become an important substitute for products derived from imported petroleum.

LPMeOH technology has the potential to be a more efficient, lower cost means of producing methanol from coal than the current commercial processes, which must be licensed from foreign firms and which were designed to produce methanol from natural gas -- a premium fuel itself. Progress to date in the program has been encouraging. Research work has begun to confirm our belief that LPMeOH technology is particularly advantageous when the starting raw material is coal. Early results suggest that the liquid-phase methanol process is capable of accepting synthesis gas of varying carbon monoxide (CO) and hydrogen ($H_2$) contents, and in particular, gases with the high CO/$H_2$ ratios that are typical of modern, thermally efficient coal gasifiers. Furthermore, LPMeOH produces a higher CO conversion per pass, and permits more efficient recovery of the heat liberated during the CO/$H_2$ reaction. Hence, tangible progress has been made in developing the potential of LPMeOH. This potential must now be verified and expanded through additional research. Research needs continue to be of a long-range, high-risk nature. Testing novel process concepts, taking a large amount of data under different operating conditions, developing novel catalysts, and otherwise extending the fundamental technology base of the process are important future steps.

Our proposed continued work contains a very strong element of generic technology development that will be applicable to a host of technology development needs in coal liquefaction. In particular, the project involves fundamental research on the behavior of three-phase (gas/liquid/solid) reactors. This research will be done in a facility large enough to permit the study of the engineering variables that affect process performance and it will lead to an improved understanding of the fluid mechanics of three-phase systems, which should have relevance to other coal conversion processes. In particular, the increased knowledge obtained from this research will aid in development of the Liquid Phase Fischer-Tropsch technology which is presently at a less developed state than LPMeOH.

Operation of the LaPorte PDU along with supporting programs is more than just another project in DOE's fossil energy budget. The LaPorte facility presents the country with a unique opportunity to perform cost-effective research to obtain the data and develop the technology necessary for the deployment of a synthetic fuels industry during the next period of national need. Despite the rather speculative, and certainly long-range nature of research at the LaPorte PDU, the fundamental attractiveness of the technical approach has led to strong industrial support. Both Air Products and EPRI are committed to the long term development of LPMeOH technology and to cost sharing in the proposed program. CSI, the originator of the technology, continues as a partner in the program.

In summary, there are a number of reasons why the government should support this key project in DOE's indirect coal liquefaction program:

1. Indirect liquefaction is an innovative, promising way to convert the nation's abundant coal resources into clean, liquid fuels that can substitute for liquid fuels produced from imported petroleum.

2. The proposed project is basic to DOE's overall program in indirect liquefaction. It contains a large component of generic research that will be broadly applicable to coal liquefaction.

3. Methanol, the end product of the LPMeOH technology, holds promise as a clean, premium fuel in a variety of applications. Methanol from domestic coal could become an important substitute for products derived from imported petroleum.

4. The LPMeOH technology has the potential to be a more efficient, lower cost route to producing methanol from coal than conventional gas phase processes.

5. The proposed project is structured in a way that makes sense from both a government and private sector viewpoint. The program uses an existing, cost-effective government owned facility, the LaPorte PDU, in which DOE has invested $8 million. The broad private participation indicates that this research, if successful, will not languish for lack of interest or capability.

6. The high-risk, long-term nature of this project limits industry's ability to undertake this effort without government participation.

Historical parallels should make our current situation clear. If we are faced with yet another oil crisis and have not progressed in synfuels technology development, our response to the crisis will be incomplete and inefficient, and we will be at the mercy of foreign oil interests who will once again dictate both price and supply. Fortunately, the Federal Government can avoid this situation by playing an aggressive role in the development of advanced, innovative technologies of strategic value to the country. Use of the LaPorte PDU is one cost-effective way to develop such technologies, and we hope it will receive continued support.

Thank you for your attention and the opportunity to testify before your subcommittee. I will be glad to answer any questions you may have.

Mr. BOUCHER. Thank you, Dr. Roberts.
Mr. Yeager.

## STATEMENT OF KURT E. YEAGER, VICE PRESIDENT, COAL COMBUSTION SYSTEMS DIVISION, ELECTRIC POWER RESEARCH INSTITUTE

Mr. YEAGER. Thank you, Mr. Chairman.

I am Kurt Yeager, vice president and director of the Coal Combusion Systems Division of the Electric Power Research Institute. I appreciate again this opportunity to meet with you to discuss both the EPRI and the Federal programs in coal combustion related research and development.

My comments will summarize some of the points in my testimony that I previously submitted.

Although coal is by far our most abundant domestic fossil fuel resource, there are a number of barriers that continue to impede the realization of its potential. These include, first, the deteriorating quality of the coal being produced and consumed by the utility industry, increasingly stringent environmental requirements, generally declining performance of the coal fired powerplants in operation today, complexity and time required for construction and operating with respect to new plants, and of course, as a result of all of that, escalating costs.

Resolution of these barriers has been the common goal of both Federal and private sector coal utilization R&D efforts.

Environmental constraints are, of course, clearly intertwined with the issue of coal utilization. Of particular immediate concern is the politically charged issue of acidic deposition where proposed legislative action has targeted on coal fired plants. A major consideration in any such proposed action are the implications for coal utilization research and development.

As discussed in my testimony before this subcommittee on September 20, 1983, EPRI has proposed an accelerated national environmental R&D program to resolve these uncertainties.

The next 5 years are critical to R&D efforts to solve the questions surrounding the acid rain issue. These include an accurate characterization of natural resources at risk, the economic consequences of different control actions, and the most cost effective courses of action to protect sensitive resources.

For EPRI and the utility industry, this means accelerating our already substantial environmental research in this area, as well as stepping up efforts to develop new technologies that offer cleaner coal utilization. The $175 million the Institute plans to spend over the next 5 years on science and technology directly related to acid rain will be in addition to $300 million effort focused on advanced technologies such as fluid bed combustion and coal conversion that will generate electricity from coal cleanly and efficiently.

Based on the encouraging results of this R&D program to date, we believe that national emphasis on advanced clean coal technologies can have a much more significant environmental benefit than the costly, what I would consider Band-Aid retrofitting of middle-aged boilers. In fact, the combination of coal cleaning, fluid bed combustion, and slurry fuels can achieve about a 20-percent increased power output per ton of coal produced and also provide a substantial reduction in both sulfur oxide and nitrogen oxide emissions.

Unfortunately, today, no mechanism has been established to assure prompt demonstration and commercialization of these developmental technologies.

I am particularly concerned that as a result, foreign countries, where more cooperative partnership exists between government and industry, that they are aggressively moving to assume leadership of the development and commercialization of improved direct coal combustion technology. By comparison, commercial development of coal technology in this country, an area where the United States has been the historic world leader, has stagnated for the last 20 or 30 years. The question is not whether we know how to burn and use coal cleanly, but whether there will be truly the incentives provided for its commercial application.

The next 5 years are particularly critical to recapturing our national leadership in coal utilization. The reason for this is that by the 1990's, there will be a new wave of utility construction which will be necessary to keep pace with electricity demand and replace aging hardware. An aggressive joint Federal/private program now will assure that the best technology to meet the performance and environmental demands of that time are available. Lacking such an effort, I am concerned that the Nation will continue to depend on obsolete technology combined with Band-Aid environmental controls that reduce productivity and only move rather than solve the various environmental issues.

Loss of technical leadership may also force the utility industry to depend increasingly on foreign sources of supply.

I would like now to turn to a few specific comments on six program areas in the both the DOE program and the related EPRI program. The first would start in coal quality. Coal quality and its improvement is central to the efficiency, reliability, and environmental performance of coal utilization. There is really no single area that is probably more cost effective in terms of improving the quality and capability of our coal utilization.

We are pleased to see an accelerated Department of Energy program in coal preparation. Part of this effort will be a joint project with the Electric Power Research Institute to develop advanced cleaning technology for improved sulfur and ash rejection and its broad application over a variety of fuels. The test bed for this effort will be at the EPRI coal cleaning test facility in Homer City, PA.

We would also strongly encourage additional efforts in reducing the fouling and slagging difficulties associated with the use of lower ranked fuels, which become increasingly into use as we move in the environmental arena.

The second area is perhaps one which has the greatest payoff and that is greater emphasis on resolving the issues which today limit the effectiveness of the mandated flue-gas and other environmental control technology required in the utility industry . These limitations combined with uncertainty over the future course of regulatory requirements are probably the greatest impediment to increased coal utilization.

Of particular importance is the need to focus on the identified reliability and cost problems and commit jointly with the private sector to a resolution. I underscore the joint area because I think this is an element that has been missing. We really need the joint programs between Government and the private sector.

Priority requirements include, of course, flue-gas to sulfurization, but also waste characterization, disposal and utilization, and particulate control. Much of the emphasis in the environmental arena happens to fall in the air side of things, but we must remember that everything that we do in the air, take out of the air, has to be disposed of or dealt with in some other media. That aspect, those other media, the water and solid waste sides of the issue are largely overlooked in the rush to move in the air side.

A variety of facilities have been established by EPRI and the utility industry to help accomplish these joint objectives. We would strongly encourage the DOE to participate with us in a new high sulfur emissions control test center that the EPRI and utility industry are initiating and which they have pledged $15 million to already.

The third area is the highly publicized furnace limestone injection or LIMB technology. Although this activity is administered by EPA rather than DOE, I would like to make a couple comments on it because we are somewhat concerned about the divergence in what, to date, has been a complementary effort between the Federal and private sectors. The effort is now moving from an industry side to a series of 40- to 100-megawatt prototype tests which we believe should be an integral part of any development process.

This allows us to test a variety of operating conditions that are crucial to acceptance of this technology. The Federal program, on the other hand, is tending to leapfrog this step and move on to even larger scales without having set what we would consider an adequate development base for its successful application.

We would like, therefore, to encourage EPA to participate in these prototype projects, thus creating a truly national program joining the capabilities of the public and private sectors.

The fourth area is in the advanced combustion technology area. We believe that more attention needs to be paid to an expanded combustion research and testing capability, particularly the availability of larger combustion facilities in this country. We are almost unique among the advanced countries of the world in our lack of large combustion facilities for the prototype testing of burner designs, boiler designs, control systems, and so forth.

This puts us at a substantial disadvantage to Europe and Japan where these facilities are used and, in fact, are used under contract, often by our own manufacturers.

We also think the DOE should stay active in the participation in the development of the coal water slurry area which you heard about earlier from Dr. Wolfe. This is an important oil backout option for the utility industry and for industry in general. There are a number of development issues that we think continue to need attention, and I have described those in my written statement.

A fifth area is in fluid bed technology, and I would like to underscore some of Dr. High's comments. This is an area that I think provides a truly successful prototype of the kind of joint participation that has characterized this area in terms of joint Federal and private participation. As a result of this carefully developed and sequential development activity between the Government and the private sector, we are now moving to three large utility demonstrations to confirm the viability of atmospheric fluidized bed combustion as an improved method of coal utilization.

You heard a bit from Dr. High on the new demonstration program with TVA, Duke Power, and Commonwealth of Kentucky project to build a new 160-megawatt boiler at the Shawnee power station. EPRI is planning to commit $75 million to that particular effort.

There are two other demonstrations that should be commented on, however. The first is by Northern States Power, a truly commercial demonstration, to modify an existing pulverized coal boiler to fluidized bed to pickup additional capacity in the process and to extend the life of the plant.

The third demonstration that is also being initiated with Colorado Ute on the western slope of Colorado using the lower grade fuels in that area. That will provide a new circulating bed boiler.

All three of those projects are complementary and we believe will provide a very solid base for decisions to move in this technology.

The last area of technology that I would like to touch on this morning is pressurized fluidized bed combustion which we believe will provide further advantages, both in modularity, the ability to build smaller units of power at a time when both the growth and cost of power are very high, and this is a new demand area that pressurized fluidized bed combustion can fulfill, we believe, best of any of the new coal technologies.

Successful achievement of these advantages, however, continues to depend on the operation of both the Grimethorpe PFBC facility in England and the Curtiss-Wright pilot plants here in the United States. At Grimethorpe today, U.S. testing of two different tube bundle designs by U.S. boiler manufacturers are planned in 1985. Fortunately, it appears there will be a strong base of support from the United Kingdom for the continued operation of the facility, thus permitting a more streamlined DOE participation.

Second, the operation of the Curtiss-Wright facility, in our view, is necessary and essential because of some of its unique capabilities. It is the only PFB facility anywhere in the world which provides for the integrated operation of both the boiler and a gas turbine. In this manner we are able to test both integrated control of the system, develop hot gas cleanup technology, as well as sheer turbine reliability.

That facility, which has been built but not yet operated by the Department of Energy, today the DOE is considering a cost-shared proposal, led by the Public Service Electric & Gas Co. of New Jersey, together with Burns & Rowe and several other private sector companies, for a 21-month test program on that facility that we believe would go far to resolving these uncertainties. If both the Grimethorpe and Curtiss-Wright facilities are successful over the next year or two in their individual test programs, EPRI, individual utilities and the boiler and turbine manufacturers are preparing engineering designs for modular pressurized, fluidized bed power plants that can build this decade if the essential pilot plant projects are successfully completed.

I would conclude my testimony by simply underscoring the fact that we have today no shortage of opportunities to improve the efficiency, reliability and environmental performance of our coal combustion. Successful achievement of these objectives, however, requires a much more constructive and coordinated partnership between Government and the private sector. I think only in the atmospheric fluidized bed area can I point to an area where this kind of coordinated development has occurred, and I think you can see for yourself the commitment that the private sector is making as a result.

These coordinated efforts need to encompass not only the planning and implementation of R&D, but also the commercial transfer of results. The rate of commercialization and use of improved technology also will depend on the development of regulatory and economic incentives which will encourage the introduction of innovative technology. Too often we find that our dependence on the adversarial approach to resolution of conflicts in energy and environmental areas only makes our use of coal more severe, more difficulties in its use, more severe and disruptive than necessary, and restricts rather than encourages the introduction of technological improvement.

Thank you very much for your attention. I would be happy to answer questions.

[The prepared statement of Mr. Yeager follows:]

STATEMENT OF

KURT E. YEAGER
VICE PRESIDENT, COAL COMBUSTION SYSTEMS DIVISION
ELECTRIC POWER RESEARCH INSTITUTE

BEFORE THE
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

MARCH 6, 1984

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## Introduction Statement

Mr. Chairman, Members of the Subcommittee:

I am Kurt E. Yeager, Vice President and Director of the Coal Combustion Systems Division of the Electric Power Research Institute (EPRI). I appreciate this invitation to meet with you to discuss the Federal Programs in coal combustion related research and development. These programs have significant implications for the electric utility industry and therefore are of great importance to EPRI.

The Electric Power Research Institute was established by the Electric Utility Industry in 1972 to conduct a broad research and development program for the entire electric utility industry and its rate payers. EPRI's R&D mission is to develop new and improved technologies for electric power production, delivery and use, and to help accelerate their availability to insure an adequate supply of economic, reliable and environmentally acceptable electricity.

EPRI is supported by voluntary contributions from investor-owned, government-owned and cooperatively-owned electric utilities across the nation. Over the next five years, EPRI will direct about $370 million to improving direct coal combustion systems. In terms of allocation of the EPRI Coal Combustion Systems Division's effort, the largest part of our work is focused on the next ten years, providing improvements in performance and reliability of existing power plants and environmental control. The remainder of the Division's effort is devoted to next generation coal combustion technology, especially fluidized bed combustion and coal slurry fuels. The 1984 budget for the activities can be summarized as follows:

| Activity | 1984 EPRI Expenditures ($10^6$$) |
|---|---|
| Fuel Quality | 7.2 |
| Flue Gas Cleanup | 13.4 |
| Heat, Waste and Water Management | 7.1 |
| Power Plant Availability & Performance | 12.7 |
| Fluidized Bed Combustion | 11.6 |

Since its inception, EPRI has worked with the Department of Energy (and its predecessor agencies), the Environmental Protection Agency, and other federal agencies with energy research and development responsibilities to achieve mutual technical objectives.

My testimony today will focus on these EPRI programs in coal combustion technology development and their relationship to corresponding Federal coal programs.

## The Role of Coal

Coal is by far our most abundant domestic fossil fuel resource and has been the cornerstone of the national goal to achieve increased energy self-sufficiency under each of the last four administrations. The imperative for coal has grown rapidly over this period as the reliability and security of our petroleum supply has become more uncertain and the nuclear power initiative has been increasingly delayed. In addition to providing about 60% of the electricity generated, today, coal is expected to provide about two-thirds of the nation's energy growth over at least the next 30 years. The large majority of this growing coal utilization will be in the form of direct coal combustion, primarily by the electric utility industry.

There are, however, several barriers which continue to impede the realization of coal's potential. These include:

- o Deteriorating quality of the coal produced, not only in absolute heating value and combustion behavior, but in the day-to-day variations of these properties.
- o Increasingly stringent environmental control requirements.
- o Generally declining performance of coal-fired power plants.
- o Scarcity of uncommitted water supplies.
- o Complexity and time required for construction and operating permits.
- o As a consequence of all the above, escalating costs.

Resolution of these barriers has been the common goal of both Federal and private sector coal utilization R&D efforts.

## Environmental Constraints

Of particular immediate concern is the politically charged environmental issue of acidic deposition where proposed legislative action has targeted on coal-fired plants. A major consideration in any such proposed action is the implications for coal utilization research and development.

The issue of acidic deposition has forced a national reexamination of control strategies aimed at reducing sulfur dioxide ($SO_2$) and nitrogen oxides ($NO_x$). The objective of more rapidly reducing the atmospheric loading of these pollutants has shifted the focus from new sources to the even more difficult problem of existing sources. The fundamental question, however, remains how best to control the effects of intense urbanization on the environment. Scientific uncertainty surrounding many aspects of these effects complicates the decision of whether or when to require further emission controls and from what sources. Unfortunately, political pressure to force rapid judgements on one or another emitting sector without the means for accurate, objective consideration of the total cause and effect is unlikely to be effective. Substantively, however, these judgements are sure to impose major costs on the affected sectors and our society as a whole. The key question is not whether the environmental impacts exist, but whether there is a control strategy which is technically capable of significantly reducing these phenomena at a cost commensurate with the value of the benefits to be achieved.

As discussed in my testimony before this Subcommittee on September 20, 1983, EPRI has proposed an accelerated national environmental R&D program to resolve these uncertainties.

The next five years are critical to R&D efforts to solve the acid rain issue. EPRI's proposed national research program, which expands and accelerates the federal acid rain research plan prepared by the Interagency Task Force, could provide answers by 1988 to the questions on which the success of possible solutions depends. These include an accurate characterization of natural resources at risk, the economic consequences of different control actions, and the most cost-effective courses of action to protect sensitive resources.

For EPRI and the utility industry, this program means accelerating our already substantial environmental research on acidic deposition, as well as stepping up efforts to develop new technologies that offer cleaner coal combustion. EPRI and its utility members sponsor today the largest privately funded research program on acid rain in the world. The $175 million the Institute plans to spend over the next five years on science and technology directly related to acid rain is in addition to a $300 million effort focused on advanced technologies such as fluidized bed combustion and coal conversion that will generate electricity from coal cleanly and efficiently.

Based on the encouraging results of R&D EPRI has sponsored to date, we believe that a national emphasis on advanced clean coal technologies can have a more significant environmental benefit than the costly retrofitting of middle-aged boilers.

Whether or not widespread additional action is taken against existing coal-fired power plants, no single solution will satisfy the widely varying conditions in these plants. There are several basic control approaches and any number of technical variants, all of which need accelerated development attention.

Unfortunately, no mechanism has been established to assure the prompt demonstration and commercialization of these developmental coal combustion technologies. As a result, opportunities in coal cleaning, fluidized bed and other coal combustion improvements as well as environmental control technology, all having a major impact on the quantity and quality of coal utilization over the next 20 to 30 years, are constrained from development and application without an accelerated, joint federal and private effort.

## Research Objectives

Key objectives with respect to coal combustion related technology which should be emphasized under such a joint federal/private effort include the following:

- Provide improved characterization of our domestic coal resources.
- Develop improved coal quality control and assessment technology.
- Improve the performance and longevity of conventional coal-fired installations.
- Improve the cost and reliability of environmental control technology.
- Develop clean, modular, quickly sited new coal-fired technology which will reduce the cost of energy utilization to both consumer and stockholder.
- Provide economic and regulatory incentives to insure the rapid commercial utilization of technology improvements.

## Issues Facing the Private Sector

The role of the private sector in carrying out this R&D must consider the unique aspects of the primary using industry-the electric utilities, and their technology suppliers:

- The electric utility industry is a financially stressed, regulated industry. Rates of return are governed by public utility commissions, and therefore, profits do not necessarily reflect risks.

- Energy tax credits for new technology, permitted other industries, are not available to electric utilities.
- Financial problems facing the industry and its inability to generate capital funds for improvement or expansion makes additional R&D funding even more difficult. As a result, EPRI has also had to reduce the scope of its program and funding at a time when the needs are increasing dramatically.

- Major financial risk is associated with incorporating an innovative technology into an established and complex electric power system so that it is both economical and reliable.
- Utility supplier firms cannot afford the investment in R&D necessary to return a sufficient profit in these times of uncertain interest rates and limited, short term, markets. R&D is only the first step in a project which, if successful, will require time and orders of magnitude greater expenditures for engineering, manufacturing, marketing and capital before a profit is realized. The possibility of changes in government policies over the period further amplifies the risk.
- Under these cost conditions, and with reduced domestic economic growth, the utility suppliers are turning more and more to serving a less sophisticated third world market with existing technology. In that market improved efficiency and environmental control are lesser considerations in the use of coal. Thus a fundamental change in supplier priority may develop which is not compatible with the utilization objectives for coal in this country or for keeping U.S. technology in the forefront.
- Foreign countries, where a more cooperative partnership between government and industry exists, are aggressively moving to assume leadership in the development and commercialization of improved direct coal combustion technology.
- Loss of technological leadership may force the utility industry and its suppliers to depend on these foreign sources. Thus the free-market may work on an international level for the user. The U.S. will, however, lose the trade advantages of exporting rather than importing technology. Other, far-searching implications for supplier confidence and the U.S. international position are self-evident in such a loss of leadership.

Taken together, these circumstances continue to pose a problem of major proportions - a problem which should be of national concern. It becomes especially critical when it is necessary to build large-scale demonstrations. These are essential elements in proving out the reliability, economics and technical capability of new technologies. It is also often necessary to gain experience with several such large-scale projects before the risks are reduced to the level of broad commercial acceptability, especially in the utility industry where reliability of service must take first priority. Thus, there are a number of programs in direct coal combustion related technology for which the funding mechanism to achieve prompt development and application is not evident. These are necessary to resolve the issues constraining coal use today and for the foreseeable future.

## PROGRAM COMMENTS

### 1. Coal Preparation and Analysis

Coal quality is central to the efficiency, reliability and environmental performance of coal combustion. Coal cleaning to remove sulfur and ash is therefore an increasingly important option for the utility industry and is one of the most underdeveloped areas in coal combustion related technology. Priority objectives for research and development to improve coal quality forecasts and technology include:

- Improved sampling and analytical procedures to insure confidence in our reserve quantity and quality estimates.
- Techniques for improving the slagging and fouling characteristics of lower rank, Western coals.
- More efficient and economical fine coal cleaning and recovery techniques.
- More economical chemical cleaning techniques providing thorough sulfur and ash removal.
- Automated cleaning process control and on-line continuous measurement techniques to improve reliability and product quality.

Important supporting research areas include: Coal communition (ways of crushing coal to micron sizes without excessive energy consumption are a major requirement for ultra-clean coal production); coal mineral matter reaction chemistry (currently we have a very poor understanding of the actual forms in which mineral matter occurs in coal, let alone how it reacts in chemical processes); coal organic sulfur chemistry; coal surface propoerties; general coal chemistry; anc construction materials development.

DOE support for coal preparation has been productively accelerated in the FY1985 budget proposal. Part of this proposed effort is a joint project agreement with EPRI to develop advanced fine coal cleaning technologies which offer improved sulfur and ash rejection along with improved coal recovery and economics. The bulk of this effort will be conducted at the EPRI Coal Cleaning Test Facility (CCTF) located in Homer City, Pennsylvania. This facility is hosted and co-sponsored by Pennsylvania Electric and New York State Electric and Gas.

The extensive application of improved coal cleaning technology results from this joint effort can be, for example, one of the more cost-effective means of reducing sulfur dioxide emissions. Several significant additional benefits could also accrue from improved coal cleaning processes. The value of these benefits will, of course, vary and must be determined on a site-specific basis.

- Reduced transportation costs.
- Improved power plant reliability and performance.
- Reduced waste disposal costs.
- Reduced flue gas cleaning requirements.

## 2. Flue Gas Cleanup

### A. Flue Gas Desulfurization

Flue gas desulfurization (FGD) so called wet scrubbing, has been defined by EPA as the Best Available Control Technology (BACT) for control of $SO_2$ emissions. It is therefore mandated on all new power plants and is currently applied to over 110 generating units with about 100 additional scrubbers under construction or contract by the utility industry.

Unfortunately, over the past decade FGD systems to control $SO_2$ emissions from coal-fired power plants have proved to be among the most costly and least reliable pieces of equipment in the utility industry. Accounting for about 25%

of the capital and operating cost of a new power plant, these FGD systems on high-sulfur coal have typically experienced severe corrosion and plugging porblems and have seriously detracted from the availability of the affected power plants. The $175/kW or more capital cost of FGD on a new plant is exceeded only by the cost of the boiler itself. Maintenance cost of the FGD system is two to twenty times the maintenance cost of the rest of the power plant. As a result, the National Research Council in its 1980 report on FGD technology recommended that highest priority be given to improving the reliability of FGD systems for application to high-sulfur coal.

These operational limitations associated with the required flue gas cleanup technology, together with uncertainty over the future course of environmental regulatory requirements cause the greatest impediment today to the increased use of coal.

Retrofitting an FGD system to an existing power plant, as proposed under acidic deposition legislation, is typically more difficult and expensive than on a new power plant. This results from the necessity to apply a complex chemical process to a plant not originally designed to accept it.

This will typically increase the capital cost of a retrofit FGD installation by 25% to 40% relative to a new scrubber. However, many instances have been identified where a 100% or more cost increase is expected. These estimates do not include the added cost of power plant downtime while ducts and stacks are being prepared for the FGD system. The levelized cost of these retrofit FGD installations may typically rival the present busbar cost of the electricity produced by the power plants.

Based on these limitations, retrofit FGD systems in their present form represent only a band-aid solution, often creating as many problems as they solve. They should be replaced by more effective technology as rapidly as possible.

The EPRI R&D program to improve this unacceptable FGD performance is the largest of its type in the country today with $50 million invested to date and an equivalent amount planned for the next five years. It emphasizes failure cause analysis, improvements in process chemistry, materials of construction, water and energy use, hardware design, plus performance data collection and interpretation. In addition, EPRI is actively pursuing the development of improved FGD designs capable of reducing byproduct production and substantially improving cost and reliability. These include demonstrations of both the Aqueous Carbonate Process (with EPA, ESEERCO & NYSERDA) and the Chiyoda 121 Process (with Gulf Power, Southern Co. Services & others)

Several years ago, federal leadership for the development and evaluation of flue gas cleanup systems was transferred from EPA to DOE. This was applauded as a progressive step promoting resolution of reliability, performance and byproduct issues limiting the effectiveness of mandated control technology, particularly FGD. Many opportunities for flue gas cleanup technology improvement exist and cosponsored projects with utilities and others have been developed for federal participation but, to date, have not been implemented.

I am, therefore, pleased that DOE has proposed a budget increase in 1985 to address the reliability and cost issues impeding the effectiveness of FGD, with special emphasis on retrofittable FGD technology. EPRI hopes to work with DOE to help define and implement the substance of this effort. We suggest this include several joint process characterization and testing activities which were previously cancelled by the DOE, plus the following objectives:

o Develop an improved design base for retrofit scrubber applications.

o Characterize and improve the reliability of existing slurry (lime/limestone) scrubbing systems, including spray dryers, on high sulfur coal.

- o Demonstrate advanced FGD systems which reduce or eliminate the inherent limitations of current FGD technology such as reliability, byproduct disposal and cost.
- o Develop dry, retrofittable FGD processes which can be integrated with existing particulate emission control systems.

This last objective should include post-combustion lime injection which has proven to be an encouraging area of development based on EPRI efforts at our high sulfur baghouse facility cosponsored with Gulf Power Company and Southern Company Services.

I would also encourage DOE participation in a new EPRI initiative to establish a High Sulfur Emission Control Test Center. Site selection and engineering design for this facility are currently underway. The Center will provide the capability to diagnose and resolve chemistry, materials, and component reliability issues plaguing FGD scrubbers and related control technology on high sulfur coal. The Center will consist of a series of various sized scrubber pilot plants with supporting laboratories, all operating on high sulfur flue gas produced by a coal-fired utility boiler. EPRI and the utility industry have planned $15 million for this effort.

B. Limestone Injection (LIMB) Technology

Although Federal support for this technology development is focused through EPA rather than DOE, I would like to comment on the scope and direction of this support. The concept of direct furnace injection of limestone in conjunction with low $NO_x$ burners has emerged as a potentially lower cost approach for simultaneously controlling $SO_2$ and $NO_x$ emissions from existing, coal-fired power plants. EPRI and the utility industry (Southern Co. Services and others) are pursuing a major program aimed at determining the commercial viability of this technology. Our research approach to date has been generally complementary to the EPA LIMB program, however the strategies for scale-up of the technology are significantly different.

The research projects conducted to date have layed the groundwork for prototype tests at a number of utility boilers in the 40-100 MW size range. If successful, these would be followed by one or more commercial (400 MW or larger boiler demonstrations). We believe that these prototype tests are an integral part of the development process to provide the confidence for demonstration and ultimate commercial application. The issue here is the impact on the performance and reliability of the boiler and particulate control system, not just $SO_2$ removal efficiency.

This approach is, however, substantially different than the commercialization path which EPA is now pursuing, which involves as a next step moving immediately to a demonstration at a single 250 MW (or larger) utility boiler. For the following reasons we believe the EPRI/utility approach has a much higher probability of promptly determining the operational potential of this technology.

- The prototypes will enable final optimization of process design and the resolution of retrofit and performance issues that cannot be fully accomplished in the laboratory. The cost of performing this experimental work at a full-scale boiler would be prohibitive. Furthermore, we feel that the design and operation of limestone injection systems with the flexibility necessary to perform this work would be more practical at smaller boilers. These boilers would also be more likely to accommodate the load demands and frequent outages required in any case.
- The prototype approach will enable verification of process design under the range of conditions representative of larger utility boilers, but without the risks to generating equipment that would be associated with a larger full-scale boiler test program. We feel that any limitation in scaling-up the prototype results to larger boilers is far outweighed by the greater opportunities to evaluate various furnace geometries, burner designs and coal properties within a reasonable budget.

- The multiple prototypes also provide greater opportunities to involve more utility companies, manufacturers and A&E firms directly in the development effort. We feel that maximizing the private sector involvement in this work is critical in accelerating the acceptance and application of the technology.
- The prototype approach will diversify the research funding to several regions of the country, thereby increasing the likelihood of outside cofunding that would be originating from local sources including state agencies, sister utility companies or other interested groups.
- Utilities are much more willing to make available a variety of boiler designs in this size range where the risks of performing engineering development on a larger boiler would be unacceptable or unaffordable.

We have thus far identified nine utility companies that are interested in participating in this prototype effort either financially and/or hosting the tests. In addition, several state agencies have indicated an interest to participate in this work.

For the reasons outlined above, we believe that EPA participation in these prototype projects would be the most effective way to meet our mutual goals and achieve the greatest progress with the available resources. This would create a truly national program, joining the capabilities of the public and private sectors for this important objective.

We are anxious to continue our cooperation with EPA in this technology as the development efforts now begin to progress from the laboratory to the field. The increasingly larger costs associated with these efforts would seem to make this desirable for both our organizations. I sincerely hope that EPA will consider the opportunities of participating with EPRI and the utility industry in these prototype projects.

C. Particulate Control

The retrofit application of in-furnace or certain other flue gas emission control technologies will have a detrimental effect on the performance and reliability of existing electrostatic precipitator (ESP) facilities at these plants. This degradation will result from both the increased particulate loading as well as the effects on fly ash resistivity, adhesivity, and particle size resulting from changes to fly ash and flue gas composition by the retrofitted control processes.

It will, therefore, be necessary to upgrade existing ESP technology including development of improved flue gas conditioning additives, pulsed power supplies, on-line performance diagnostic instrumentation and improved fly ash properties prediction methods. This effort should include full-scale field evaluation of retrofit effects plus verification of performance improvements. The result will be utility proven techniques for maintaining and upgrading ESP performance and reliability plus guidelines for the operation and maintenance of the upgraded ESP facilities responding to new $SO_2$ and $NO_x$ control requirements.

In conclusion, the effectiveness of Federal funding in the category of flue gas clean-up will depend on an R&D policy which focuses on the problem areas indicated and commits jointly with the private sector to the technology projects required for their resolution.

3. Waste Management

Little attention has also been given to date to secondary pollution questions associated with air pollution control, notably compliance with Clean Water Act/NPDES and RCRA. In addition to a very large increase in both solid and liquid waste products created by retrofit control requirements, these requirements will produce byproducts of different characteristics--e.g., more soluble calcium in waste solids from furnace limestone injection than conventional wet limestone scrubbing.

In conjunction with planned EPRI programs for integration of the cooling tower with the $SO_2$ scrubber loop plus FGD chemistry, sludge disposal and groundwater protection, a full-scale integrated water treatment and solids management system at one or more existing plants should be constructed and tested. The system should focus on retrofit applications and be designed along with retrofit $SO_2$ controls. The effort would demonstrate application of retrofittable water quality control technology plus design and operating guidelines for retrofit water and solid waste handling systems.

The significance of this issue can be gauged by the fact that utility waste disposal costs have increased from an historic level of $2-5 per ton to $12-25 per ton, depending on local regulatory interpretations. This results in a current national utility disposal cost of $1 billion per year. Proposed acid rain legislation could more than double this cost. Even more important is the resulting impact on land utilization. For example, high sulfur FGD scrubbers on a 1000 MW power plant will typically produce one square mile of waste sludge, a foot deep for every year it operates.

DOE work in the disposal area (characterization of coal power plant waste and economic assessment of the effects of RCRA) has been effective and should be continued. For example, an extensive data base on waste characteristics and current practice has been initiated.

I would also recommend that DOE remain active in developing waste utilization alternatives. Private sector efforts are moving toward establishing a sound basis for choosing ash as an alternative raw material for road bases, land fill, structural aggregate, and cement substitutes. This may require several large demonstrations to develop generic (rather than site specific) information. The using industries (highway/building constructors, etc.) are fragmented. No easily identified commercial entity exists to fund such work but the cost savings and resource conservation value to the nation could be substantial.

Similarly, resources from ash (particularly aluminum, iron, vanadium) has the potential for meeting a large portion of our needs which are currently met by imports. Many of the benefits (balance of payments, freedom from foreign sources, national security, price stability) are difficult for private commercial funding sources to quantify and show an economic return. Federal support of such objectives is appropriate and essential.

4. Gas Stream Cleanup

The most critical application of gas stream cleanup to the direct combustion of coal is in pressurized fluidized bed combustion (PFB). The technical and commercial success of this technology as an electric power generating system depends on the ability of the gas turbine to operate reliably on the dust laden gas steam produced by the PFB.

The DOE program provides much of the research and evaluation for the new and yet unproven cleanup technology that will be required to achieve a viable PFB electric power generating system. As a result, considerable progress has been made in the technology of gas filtration at elevated temperatures and pressures. Valuable scientific and engineering information has been obtained on several types of filters over a range of PFB combustion gas conditions. EPRI plans to scale-up the results from this DOE program to confirm commercial performance and reliability leading to application in modular utility PFB power generating units.

5. Advanced Combustion Technology

A. Combustion Development

The proposed DOE effort infers that the technology base for increased utilization of coal, especially low rank coal and coal-liquid mixtures, is well established. In my judgement such is not the case. Areas particularly meriting additional effort include:

- Characterization of coal ash chemistry and its effect on combustion.
- Standardization of slagging indices.
- Effect of coal particle size on slagging/fouling.

Achievement of these objectives, which may be further accentuated if coal cleaning and switching are increased to meet emission control requirements, will first require expanded combustion testing facilities. These should include both improved, one to five million Btu/hr experimental combustors for the rapid and flexible characterization of fuel combustion properties and a larger 100 million Btu/hr facility whose results could be directly extropolated to commercial scale furnaces and boilers. It is also essential that the smaller facilities be instrumented to measure the transient chemical and physical parameters throughout the combustion process as well as the properties of the resulting gaseous and particulate products. This capability could, for example, apply state-of-the-art measurement techniques developed with DOE support at the Sandia Combustion Facility. It might be most effectively implemented in conjunction with a stable university research program to achieve much needed national centers to excellence in coal science.

At the present time, no large 100 million Btu/hr scale combustion facility exists in the United States. Not only does this limit confidence in the effects of changed fuel properties on boiler reliability and performance but it also places U.S. boiler equipment suppliers at a significant disadvantage relative to countries such as Japan where this type of facility exists for engineering development of new technology. In this regard, such a facility can be used to develop new burner and boiler hardware under conditions responding to the rapidly changing environmental and fuel use requirements affecting industry and utilities. Since such a facility exceeds the ability of any single private organization to build and maintain, a joint Federal/private sector is suggested.

We, therefore, encourage the DOE effort to consider existing facilities, such as BI-GAS in Homer City, Pennsylvania, as a site for such a combustion test center. It could build on the existing coal handling and support infrastructure and would be accesible to the EPRI Coal Cleaning Test Facility as a source of characterized coal whose composition could be varied to meet specific combustion requirements. As a first step, the collective industrial requirements for such a facility should be further analyzed to determine the degree to which the operating costs of such a facility could be supported.

B. Coal Water Slurry

The technology of coal-water slurry (CWS) as an oil back-out option has shown favorable development progress over the past year, based on coordinated efforts by EPRI and DOE. Of particular note was the successful, extended operation of a Dupont Chemical Company boiler in Memphis, Tennessee. This EPRI sponsored test involved the firing of 2500 tons of CWS over a continuous 45 day period in a 65,000 lb steam per hour, commercial, oil-design boiler. The CWS was prepared in Virginia and New Jersey and shipped by rail tank car to Memphis. No difficulties were experienced in the shipping, handling or firing of this fuel. The results provide the basis for further scale-up of this oil back-out option leading to large scale utility demonstrations by 1986, if sufficient CWS production capacity can be established. Eighteen utilities are now participating with EPRI in the engineering evaluation of possible demonstration sites.

In order to assure the technical foundation for such large scale CWS application, I would encourage continued DOE participation with the private sector in technology development. Areas requiring further attention include:

- Development of reliable CWS burners, capable of adjustment as coal/slurry characteristics change.
- Development of burner control and safeguard systems.
- Development of erosion-resistant convection pass tubing materials for retrofit.
- Development of high shear, slurry viscosimeters.
- Study of the environmental and economic benefits derivable from coal beneficiation during slurry preparation processes.

This would logically complement DOE and EPRI efforts to date involving slurry characterization, development of utilization guidelines, and testing of slurry handling, pumping and firing equipment.

6. Atmospheric Fluidized Bed Combustion

EPRI and the utility industry are pursuing the application of atmospheric fluidized bed combustion (AFB) as a further evolutionary improvement in coal utilization to meet the requirements of today. The improvements which excite interest include: First, reduced sensitivity to fuel quality, thus permitting use of a much broader fuel supply without suffering large losses in efficiency and reliability in a single boiler design. Second, less cost sensitivity to unit size in a period when load growth and siting restrictions may encourage smaller rather than larger boilers. A third primary advantage of AFB is environmental performance. In AFB both sulfur and nitrogen oxide control is achieved within the combustion process, thus eliminating the need for parasitic flue gas cleaning systems. These and related advantages can be summarized as follows:

- Increased fuel flexibility including low grade fuels.
- Emission control without scrubbers.
- Dry byproducts.
- Design independent of ash content or properties.
- No derating due to slagging or fouling.
- Capital and operating cost savings.

Development of AFB has successfully progressed from the process confirmation stage to engineering prototype, making commercial scale utility application possible this decade. To achieve this goal, TVA has taken the lead, with EPRI support, in implementing a 20 $MW_e$ engineering prototype at the Shawnee Power Station near Paducah, Kentucky. This facility began operation in May 1982 and has been operating successfully since. This facility was only possible through major Federal R&D support.

The success of these results provides the technical basis for 100-200 MW commercial demonstrations by the utility industry which will be operational this decade. Three such complementary utility demonstrations are now proceeding under private sector leadership.

| | Project | Location | Size | Planned Operational Date |
|---|---|---|---|---|
| o | TVA/Duke Power/State of Kentucky | (KY) | 160 $MW_e$<br>New AFB Boiler | 1989 |
| o | Northern States Power | (MN) | 125 $MW_e$ Boiler<br>AFB Conversion | 1986 |
| o | Colorado-Ute Electric Assoc. | (CO) | 110 $MW_e$<br>New Circulating AFB Boiler | 1988 |

In each case the utility industry will fund the largest share of these demonstrations with EPRI and the suppliers sharing the first-of-a-kind risk costs. Bid specifications for all three have either been issued or are in final preparation.

$160 million in private and state funds, including $75 million from EPRI, have been authorized thus far for the TVA/Duke Power/EPRI/State of Kentucky demonstration in which a new AFB boiler will be built to repower and extend the life of an existing 160 MW steam turbine/generator at the TVA Shawnee Power Station. This is the primary demonstration effort in achieving a confident basis for applying AFB as a utility generating alternative by the 1990's. Prompt availability of the $30 million in Federal funding already authorized by Congress is essential to the financial closure of this project and will help assure that the contractual award for plant engineering and construction is not delayed.

The Northern States Power AFB Demonstration provides a retrofittable utility option to reduce $SO_x$ and $NO_x$ emissions as well as reduce sensitivity to coal quality at existing, older power plants. Here an existing 100 $MW_e$ pulverized coal boiler would be converted to AFB while also increasing its capacity to 125 MW and extending plant life by an expected 25 years. This demonstration will be built and operated as a commercial effort. As a result, the cost will be partially offset by the resulting increase in generating capacity, fuel flexibility and plant life, thus making it a more cost-effective option than FGD. An examination of the utility boiler population indicates that there are a substantial number of candidate utility boilers for similar AFB conversions. They total about 25,000 $MW_e$ in 200 units built primarily during the period of 1945-1965.

The Colorado-Ute project provides yet another option. Here, a new 110 MW circulating AFB boiler will be built to repower an existing 40 MW steam turbine/generator as well as drive a new 70 MW steam turbine/generator. This AFB boiler offered by U.S. manufacturers, but reflecting a European design base, will provide a useful direct comparison, in terms of performance and reliability, with the bubbling bed designs being installed by TVA and Northern States Power.

The continuity and success of the previous combined Federal/private development effort is making these pioneer AFB demonstrations possible primarily through private support. This provides a successful prototype for similar utility and government collaboration in other areas of coal utilization R&D.

## 7. Pressurized Fluidized Bed Combustion

The new and dynamic utility climate also influences pressurized fluidized bed combustion (PFB) development. The influence results from the trend toward smaller new unit size plus utility priority on uprating the capacity of existing units to bring generation on line quickly and at the lowest cost. These advantages can translate into an effective reduction in capital costs of $200/kW to $300/kW by better matching load growth and reducing the cost of work in progress (CWIP). PFB provides the opportunity to add these advantages to the inherent fuel flexibility and environmental control capabilities of atmospheric fluidized bed combustion.

As a result, development emphasis is being placed on PFB turbocharged boilers which can provide shop-fabricated, barge transportable, steam generation modules. These may be rapidly field-erected to provide the desired uprating in unit sizes of 150 $MW_e$ to 250 $MW_e$. This approach can also use coal to replace or increase the capacity of existing oil-or gas-fired plants while meeting stringent siting and environmental control constraints. It also provides the lowest busbar energy cost of any coal-fired power generation option now under development.

Although the turbocharged PFB boiler has less technical uncertainty than the higher gas temperature, PFB-combined cycle design, considerable development is still required before the commercial potential of this option can be realized by the utility industry. This effort centers on the PFB boiler and involves the design base for the heat transfer tube bundle within the bed as well as coal feeding, ash handling and control of the PFB boiler system. The only available facility for resolution of these technical issues is the International Energy Agency (IEA) Grimethorpe PFB Pilot Facility and supporting Coal Utilization Research Laboratory (CURL) in England.

It appears more likely now that such operation will be possible, primarily through United Kingdom support. In addition, however, continued but streamlined DOE participation is encouraged to implement a U.S. test program at Grimethorpe. These tests are planned with two U.S. boiler manufacturers, Babcock & Wilcox and Foster Wheeler. In both cases, the manufacturers will design and supply heat transfer tube bundles for performance and relability testing. These tests are a key stepping stone to implementing planned PFB demonstration projects with the utility industry.

DOE has also completed construction of a unique and complementary, large PFB pilot facility with Curtiss-Wright in New Jersey. The unique capability of this facility is that it provides a complete PFB system, that is, a combined combustor and gas turbine. Although the combustor is used to heat air rather than steam, the system neverthless can effectively address several issues limiting confident PFB system scale-up:

- Unproven hot gas cleanup technology capable of operating well beyond the efficiency of inertial separators.
- Unproven gas turbine reliability.
- Need for demonstrated system availability and operability under utility conditions.

No other facility exists to resolve these technical issues. Thus, in any analysis of the path by which the PFB system performance and reliability questions will be promptly resolved, the large Curtiss-Wright pilot facility is a necessary capability.

In order to ensure operation of this critical facility, Public Service Electric and Gas of New Jersey and Burns and Roe (architect-engineer) have proposed a cost shared project to DOE for a 21 month test program. This proposal would provide the capability to resolve the several limiting PFB system issues identified above, thus satisfying the technical objectives for which DOE built this sophisticated and expensive pilot facility. EPRI strongly encourages DOE support of this proposal. We believe it is the most effective way of providing prompt testing of this facility at a time when its operation is a pacing item in achieving commercial application of PFB. EPRI also looks forward to participating in this important project, both in design of the test program and in testing hot gas cleanup devices critical to PFB system reliability.

Efforts have been initiated by EPRI, individual utilities, and the boiler and turbine manufacturers to design engineering prototypes of the PFB turbocharged boiler based on the results from these pilot facilities.

In 1982, an EPRI study by Brown Boveri identified the PFB turbocharged boiler as an attractive alternative to the combined cycle system more commonly associated with PFB systems. Follow-on studies by various turbine/boiler teams with EPRI and several utilities confirmed the potential for a significant reduction in capital cost over pulverized coal systems with flue gas desulfurization. One GE/B&W study was made site specific to Florida Power and Lights's (FPL) Palatka-2 plant, a retired 80 $MW_e$ plant located in North Central Florida. In this configuration, superheater and economizer surfaces located in the free board area above the fluidized bed reduces the combustion gas temperature to less than 800°F before it leaves the boiler. This lower temperature allows a state-of-the-art clean-up system to remove particulates from the combustion gases, minimizes turbine blade erosion, and avoids expensive high-temperature gas piping as well as the need for a heat recuperation system in the turbine exhaust.

As a result of this EPRI sponsored study, GE, B&W and FPL have continued to investigate this concept, including sorbent testing and cold flow "in-bed" tube erosion tests in the CURL PFB test facility in England and a hot gas clean-up system at GE's PFBC facility in Malta, New York. The ultimate goal of this work is the demonstration of a full-scale (100 $MW_e$) module on a utility system. FPL's Palatka-2 plant is clearly one candidate for such a demonstration, but there are other plants which would also serve for such a demonstration.

I emphasize, however, that such a commercial demonstration can only be implemented if the Grimethorpe and Curtiss-Wright results indicate, to users satisfaction, confidence in the reliability and operability potential of PFB power plants.

Conclusions and Recommendations

1. Coal quality is central to the efficiency, reliability and environmental performance of coal quality. The accelerated DOE program in Coal Preparation is therefore encouraged. Part of this effort is a joint project with EPRI to develop advanced cleaning technology for improved sulfur and ash rejection.
2. Greater emphasis should be placed on resolving the issues limiting the effectiveness of mandated flue gas and other environmental control technology. These limitations, combined with uncertainty over the future course of regulatory requirements, are the greatest impediments to increased coal use. Of particular importance is the need to focus on the identified reliability and cost problems and commit jointly with the private sector to their resolution. Priority requirements include flue gas desulfurization; waste characterization, disposal and utilization; and particulate control. A variety of facilities have been established by EPRI and the utility industry to help accomplish these joint objectives. These include a new High Sulfur Emissions Control Test Center.
3. EPRI and several utilities are actually evaluating furnace limestone injection (LIMB) technology as a lower-cost alternative to flue gas desulfurization. This effort is now moving to a series of 40-100MW prototype tests which should be an integral part of the development process. A corresponding Federal program administered by EPA should be encouraged to participate in these prototype projects. This would create a national program, by joining the capabilities of the public and private sectors.
4. New initiatives are recommended in the Advanced Combustion Technology program. These should include an expanded combustion

research and testing capability and continued participation in coal water slurry technology development necessary to assure its viability as an oil back-out option.

5. Three large utility demonstrations are currently being developed to confirm the viability of atmospheric fluidized bed (AFB) combustion as an improved method for utility coal utilization. These should provide the technical base and confidence for broad commercial application by the utility industry in the 1990's. An essential element in achieving this capability is the $30 million authorized by Congress for the TVA/Duke Power/EPRI/State of Kentucky 160 $MW_e$ demonstration. This will augment a private and state investment in these three projects of about $350 million.

6. Pressurized fluidized bed (PFB) combustion may provide further advantages in modularity and cost reduction for coal-fired power generation. The successful achievement of these advantages continues to depend, however, on the operation of both the Grimethorpe and Curtiss-Wright PFB pilot plants. Testing of tube bundle designs by U.S. boiler manufacturers are planned for Grimethorpe and will need continued, but streamlined, DOE participation. A cost-shared proposal, led by Public Service Electric and Gas in New Jersey, has been made to DOE for operation of the Curtiss-Wright facility. Implementation of this proposal could resolve the several system design and control issues limiting PFB scale-up. EPRI, individual utilities, and the boiler and turbine manufacturers are preparing engineering designs for modular PFB power plants which could be built this decade if these essential pilot plant projects are successfully completed.

7. There is no shortage of opportunities to improve the efficiency, reliability and environmental performance of coal combustion. The successful achievement of the objectives laid out in this testimony require, however, a more constructive and coordinated partnership between government and the private sector. This encompasses the planning and implementation of R&D as well as the commercial transfer of results.

8. The rate of commercialization and use of improved technology also depends on the development of regulatory and economic incentives which encourage introduction of innovative technology. Too often our dependence on the adversarial approach to resolution makes the conflicts restricting coal use more severe and disruptive than necessary and restricts the introduction to technological improvement.

Mr. BOUCHER. Thank you, Mr. Yeager.

On behalf of the committee, I want to thank all of the witnesses for their very thoughtful and well presented testimony this morning. That is very helpful to us.

Mr. High, your testimony on page 5 of your prepared statement states that you have an excellent opportunity through the use of your pilot test facility to compare a wide range of different types of fuels. What plans do you have to test fuels other than the high sulfur coal that you are testing presently?

Mr. HIGH. As I indicated in my testimony, we have about a 42-month test program in cooperation with EPRI. The latter stages of that program are being planned by EPRI and the chief component of that will be the testing of alternate fuels. I think we will test low sulfur eastern coal. I think we will test low sulfur western coals. We may consider testing some lignite, although that involves considerable handling problems for us. I think we will also probably test some of the Ohio coal.

Mr. BOUCHER. So, your plans do include testing for low sulfur as well as high sulfur coals?

Mr. HIGH. Yes; we anticipate testing a wide range of these.

Mr. BOUCHER. As a representative of a low sulfur coal producing region, I find your statement very encouraging.

Mr. HIGH. I think one of the advantages that we lose sight of sometimes in the fluid bed, we started into this of course with environmental concerns in sight, but the fact is that that technology has turned out to be very flexible and has a lot of advantages that the PC does not have. For example, ash characteristics can have a lot wider range. Coal can have a lot different quality and we can still run a unit with it.

Mr. BOUCHER. Have other firms, at this point in time, or other nonprofit associations asked that their fuels be tested in your facility?

Mr. HIGH. Well, we have had numerous requests. As a matter of fact, some of our solicitation on the demonstration plant would have involved the question, can our contribution be the coal that we would like to burn so that we have that test data. The answer to that is yes in both the power plant and the demonstration plant.

Mr. BOUCHER. Congress recently appropriated $30 million to the Department of Energy for your proposed demonstration facility. Have you had any difficulty in establishing a mechanism to receive those funds?

Mr. HIGH. To date, we have been working at the staff level with the Department of Energy in arriving at what we think might be a reasonable compromise. I am not prepared today to say that we have had difficulty. I will have a meeting next week with the new Assistant Secretary of fossil energy. Maybe at that time I can tell you more clearly what difficulties we might have. We don't anticipate any, but we are in that negotiating stage now.

Mr. BOUCHER. You have indicated that your needs for the demonstration facility are $200 million for construction and $20 million for operations, $165 million of which you presently have based upon Government funding and the funding of your participants. When do you expect getting the remainder of the moneys that you need?

Mr. HIGH. We think we have right now fairly firm commitments in the neighborhood of $200 to $206 million. We believe that is just a matter now of negotiating the contracts and developing a mechanism to get those commitments firmed up.

We think by the end of June this year, we will have the remainder of that money. In fact, what we plan to do, of course, is oversubscribe that amount in order to handle any cost overruns that we might anticipate. That is the kind of timeframe we are looking for.

Mr. BOUCHER. I assume you will defer construction until you actually have those commitments made.

Mr. HIGH. I think it is the general agreement among the four principals that have been active in this project that we will, in effect, want in our hands at least a letter of intent or a signed contract for the amount of funds necessary to carry out the project. As I indicated, later this fall we will have a much better cost estimate on this project, so I think it will be about the October time date when we expect all this to come together. We have very high confidence this will happen.

Mr. BOUCHER. Thank you very much, Mr. High.

Dr. Wolfe, let me ask about the proposed budget that you have submitted for making some changes in the budget submitted by DOE. What specific research in the area of coal liquefaction are you recommending which would be accomplished through the addition of $16 million to DOE's request?

Dr. WOLFE. I think that basically there has been a lot of work done on liquefaction. Some of the basic problems have been in the ash and the sulfur that has been involved in that. I think there is some technology that could be used that would go through two-stage liquefaction which could then also incorporate some coal cleaning along with that. Then when you do have a product, you have one that can be used without having some of the waste products associated with it.

I also believe that there are some new catalysts being developed that technology could be done to accelerate and improve the yield of that technology. Certainly, I do believe indirect and direct liquefaction are very important to still continue support for the synthetic fuels effort which can then use coal and convert it into the gasline, the mobile transportation market. That is where I would see that money being used.

Mr. BOUCHER. You have also recommended a new category for funding as our committee proceeds with its deliberations, and you have recommended a reduction in coal combustion systems funding. Why have you recommended that reduction. Is that because of the funding added to the new category?

Dr. WOLFE. Yes; I see that you really ought to bring, say, acid rain technology development out of that program and separate it so that it is clearly distinctly identified with the sulfur reductions. It is really not a reduction; it is just a realignment so that you can have a little bit of understanding of where the money is being spent, for what particular project.

I think one of the basic issues in Government funding, and having been in the Government I think I recognize it, you have to be able to identify a project that you can continue to track so that you can see what you are accomplishing. I think that sometimes you make such broad categories, you can't really track, say, an acid rain reduction program. We ought to initiate that program and in 3 or 4 years, we ought to know what we have achieved and be able to measure our results.

Mr. BOUCHER. Do you have any particular suggestions for us with regard to a program for acid rain reduction?

Dr. WOLFE. Certainly I do. I think that the acid rain reduction does not have to depend upon advanced scrubbing systems. I think anything we can do as far as technology development that eliminates the very expensive scrubbing after it has been burned is a benefit. Certainly limestone injection during the combustion phase is a technology that has been developed that should be really looked at very closely and I think some funding should be for the DOE for that program.

I also think in the area of coal cleaning to reduce the organic and pyritic sulfur and leave that particular product in the coal fields and not transport it all over the country can have a big impact.

Those are two areas that I would like to see additional funding in.

Mr. BOUCHER. The Department of Energy is working at the present time on a coal fired diesel and turbine technology. You have recommended $35 million as an additional amount for that program. What kind of research would you recommend be conducted with that additional funding?

Dr. WOLFE. Basically, the DOE program is very, very meager in diesel areas today. It is more lip service than dollars. I think that program should be specifically identified in two areas. One is trying to design the engines so that they would tolerate a little more ash and sulfur in the fuel. With the new technologies and materials development, certainly that looks feasible. I think we ought to structure the program so that we can, in the short term, have a locomotive diesel engine transporting some coal from the coal fields of Virginia to the port areas of Virginia using a coal-based fuel in a diesel engine. That technology is not that far out, and it is certainly an area that could be in the short term. I am talking in 3, 4, or 5 years when you could have that achieved.

The input to the coal industry would be an additional 40 to 50 million additional tons of coal being used in that transportation market. We had that fuel at one time with the steam engines and we lost it because of the improvements in oil and the lower cost. Now that is reversed and I think it is time we got it back.

Mr. BOUCHER. Would you anticipate the research being conducted in terms of fuel preparation or in terms of improving the capacity of the engines themselves to tolerate coal as a fuel as opposed to diesel oil, or would you anticipate the research being conducted in both areas?

Dr. WOLFE. I think in both areas. They need to go hand in hand. We ought to clean the coal and convert it just as good as we possibly can, and that involves new technologies. I think, in addition, we ought to have the manufacturers of these engines look at ways which they could burn it more efficiently and more effectively than they do today. So you have both. You have coal fuel form development plus hardware development. You can certainly build one engine or two engines a lot cheaper than you can build these big synthetic fuel plants, and I think it is a good test vehicle in which we can start to demonstrate some results, and that is what this country needs.

Mr. BOUCHER. You have also recommended an initiative with regard to coal waste recovery. Could you tell the committee what resources you would perceive being recovered from coal waste?

Dr. WOLFE. For example, the coal waste today—we are throwing away on the order of 30 to 40 percent of all the coal that is mined out of the ground and it is discarded as waste, particularly in the Eastern part of the United States where you have to go through process cleaning, and the technology in cleaning just does not recover all that carbon material. That is a resource that is really millions and millions of tons of coal that is sitting back in these coal fields today. In fact, it is so much coal in some of that they are catching fire and they are burning and emitting a lot of toxic air pollution products. It is certainly time that we start a program to recover some of that resource.

The technology is here as we apply it from some of the other areas and start to use those resources. I would certainly like to propose that TVA start considering a test burn of some of this waste product in their fluidized bed combustion system. In addition, I think there are liquid products to be gained from that waste.

Mr. BOUCHER. In the event that Congress increases the Department of Energy's coal research budget on the order of $100 million which is approximately what you recommend, how much do you think private industry would increase its contribution to the research effort nationwide?

Dr. WOLFE. I would like to say a significant amount, but I don't believe that is the case. I think that you are going to have some companies like our own and some of the other utility companies contributing, but some of this technology is high risk. Its balance scale, its laboratory bench scale, to prove feasibility—I think once you initially put that money into the program, you will see the coal industry, if they can make a dollar, they will certainly take advantage of that.

It is the same thing with the coal/water mixture fuels. Today, the Government program is almost cut back completely, and the industry is taking it on.

I think in resource recovery, if we can start recovering coal out of our waste resources, it won't be long until coal companies start seeing that as a business, and they will take it over. Certainly if you get the market developed.

So, you need this Federal funding initially as a catalyst and I think, then, once you have proved the feasibility of these concepts and the economics, it won't be any problem getting them commercialized.

Mr. BOUCHER. The Department of Energy today is looking at a number of coal cleaning technologies. You have recommended adding $13 million to the Federal research effort in this area. Would you anticipate the Department merely spending more moneys on the present research that is being conducted or are you suggesting that additional research initiatives involving new coal cleaning technologies be undertaken?

Dr. Wolfe. I certainly think that you need to establish some new technologies. They are spending about—I think in that budget coal technology and coal preparation is increased, but coal preparation has less than 50 percent of that funding in that category. I would like to see more money put into coal preparation, and that is being able to create the technology such as coal refineries rather than just coal cleaning plants.

Microbiology is one area that has had tremendous impact. That is an area that has not been looked at in great depth, but it is a technology that can be used to clean the sulfur from coal. I certainly think that that is a new program that should have some substantial dollars put into it in the area of microbiology and genetic engineering. It is being used in industrial markets, industrial sewage treatments, all use that kind of process. There is technology being developed now that shows that is certainly a feasible concept, high risk, and that is what the dollars should be spent for.

Mr. Boucher. Thank you very much, Dr. Wolfe.

Dr. Roberts, a few questions for you.

Could you explain why the liquid phase methanol production process is potentially more efficient and of lower cost than other methods of producing methanol from coal?

Dr. Roberts. Yes; today's modern, thermally efficient coal gasifiers produce carbon monoxide and hydrogen in a ratio that is quite far removed from the way today's methanol processes operate. In order to marry the best gasification technology that has come out of the past decade's research with conventional methanol technology, some steps must be inserted between the gasifier and the methanol synthesis that, basically, penalizes the thermal efficiency of the process. For fundamental scientific reasons that we don't really understand, we find that the liquid phase methanol process can accept the synthesis gas that is produced by a modern, thermally efficient gasifier directly without those intervening processes that penalize efficiency.

Mr. Boucher. Thank you very much.

If the facility which you want to continue at LaPorte, TX, remains in operation, would others in addition to Air Products have access to the facility and be able to use it?

Dr. Roberts. For the short range, we are proposing that the facility be used specifically for the development of liquid phase methanol technology. Now, there is a consortium, including EPRI, Chem Systems, and Fluor, that is involved in the development of that technology.

For the longer range, we see this as being a facility that would be available to other organizations and for other technologies in indirect liquefaction. For instance, there is a Department of Energy program in liquid phase Fischer-Tropsch technology that could be considered a follow-on program for the LaPorte facility. There are other programs that also apply liquid phase technology to different processes in indirect liquefaction that could additionally become candidates for the facility.

So, the answer to your question is yes. We see that in the long range.

Mr. BOUCHER. Thank you very much, Dr. Roberts.

Mr. Yeager, just a couple of questions.

You have advocated that advanced coal cleaning be used as an alternative to scrubbers being retrofitted in presently existing utilities as a way to address the acid rain problem. Do you think the Department of Energy's budget for coal cleaning as presented to this committee is adequate to accomplish those ends, and if not, by what measure would you recommend an increase in the budget?

Mr. YEAGER. I think the program that the DOE has today is certainly this year a good deal better than it was last year, but it doesn't begin to encompass the range of activities that we really need if we are going to accelerate the full application of that technology. I think the key issue is how far do you go into the development process. The long range high risk limitation means that you do a lot of very early development, but you never quite push it far enough to get it over the hump.

I think it is that aspect that is always of concern to me in the area that probably needs the emphasis over a concentrated 5-year period if we want to take full advantage of coal cleaning and other options of that type.

Mr. BOUCHER. Do you have a recommendation for us as to what measure of increase would be appropriate for DOE's budget this year?

Mr. YEAGER. I would be happy to provide you some information on that. I think that was in my earlier testimony. Rather than quoting a number off the top of my head, let me get that for you.

[Material referred to follows:]

*Coal quality improvement R&D*

[In millions of dollars per year]

| | |
|---|---|
| Conventional coal cleaning (reduce ultra fines generation, improve energy recovery, increase pyritic sulfur and ash removal) | $10 |
| Advanced coal cleaning (advanced physical, chemical, and biological cleaning processes including clean coal agglomeration R&D) | 10 |
| Cleaning plant instrumentation and control (improve energy recovery and product quality control by application of continuous monitoring instrumentation) | 3 |
| Low rank coal beneficiation (processes to reduce alkali and alkaline earth ash constituents and moisture which limit use of Western coals) | 3 |
| Coal reserve quality assessment (improve technology to predict in-seam coal quality and mining conditions variability) | 4 |
| Coal quality measures (develop improved coal quality measures (analyses) and measurement techniques that improve coal value quantification) | 3 |
| Coal cleanability characterization (characterize the potential for beneficiation of steam coals and determine the impact on handling and combustion characteristics) | 5 |
| Total | 38 |

Mr. BOUCHER. Fine. Thank you very much.

I am going to defer at this time to other members of the committee and will call now on Mrs. Schneider.

Mrs. SCHNEIDER. Thank you.

I wonder if all four of you panelists might be able to give us a scenario of what we might anticipate if we were to pass the DOE fossil fuel budget as it has been proposed to us. What might we anticipate in terms of development or failure to develop coal related technologies ?

Mr. HIGH. I am not sure what you refer to as a scenario. I think from TVA's perspective, we certainly would like to see the money that is in there for the fluid bed remain and be effective. I think in the area of coal cleaning, Mr. Yeager referred to that area as being somewhat lacking. I think there are some coal cleaning technologies that need to be pursued that we probably do not have at the present time enough funding in. In terms of the basic research in coal, my perspective is that we do not seem to have a complete focus on the options that are available to us and which ones we ought to pursue as long as we can afford to pursue those options and which ones we ought to narrow as those options become more expensive to us.

I am not sure that is a scenario, but that is a sense that I get out of the DOE fossil energy budget.

Mrs. SCHNEIDER. Dr. Wolfe.

Dr. WOLFE. Certainly, I think that two major points, if you fund this program the way it is right now. First of all, I think you are going to see a major stopping of some of the programs you initiated last year. That is going to take a lot of incentive, and it will take a lot of momentum that you established last year with a higher budget. So, I think it will have a devastating effect on what you have already started and waste dollars that you spent 1 year or 2 years ago.

Second, I think if you pass this budget the way it is today, you are doing a disservice to the American people. I think you are also really voting in favor of this administration's cutback on coal research and the funding of nuclear research. I think that by going along with this budget, I think you are going along with deemphasis of coal technology, and I think that speaks louder than anything else and will have more of a devastating effect on how the public perceives coal in the future. I think it will absolutely have a negative effect throughout the whole system.

Mrs. SCHNEIDER. Thank you.

Do the others wish to comment?

Dr. ROBERTS. Yes. One particular aspect of the proposed budget that is deficient and inadequate is that the programs devoted toward synthetic fuels, particularly, coal liquefaction. There are two parts of this problem that bear comment. One is that the lack of continuity in previous programs creates a situation where there will be a waste of previous money spent and a gradual erosion of capabilities in this area.

Second, there seems to be little question, that in the event of national need, the timing of which is unpredictable, the country will need a capability for converting its abundant coal resources into clean liquid fuels that can substitute for fuels derived from imported petroleum. That particular aspect of the DOE's budget is, as I said, inadequate and deficient.

Mrs. SCHNEIDER. Mr. Yeager.

Mr. YEAGER. I think the issue comes down to what do you really want to accomplish with a program of this type when you start out? It seems to me that we have been nationally rather schizophrenic on this whole topic, somewhat dependent upon the length of the gas lines at the moment.

I am not in favor of throwing money at the problem. I think the areas of the program that have been laid out, the DOE program in general, addresses the right things. It pays a certain amount of attention to a wide range of activities, probably not in enough depth in any one to really advance the technology base far enough for the private sector to go very much further with it.

Second, I don't think there is enough private sector involvement in the definition and development of the program. It is not a joint Government-private sector program. I think there needs to be more attention to the—it is not an adversarial position here. This is something that ought to be done jointly.

Mrs. SCHNEIDER. But there needs to be more private sector involvement.

Mr. YEAGER. That is right. More private sector involvement in the planning and implementation of the overall program. Now, I am pleased to see, I must say, over this past year I have seen quite a rebirth of that, a lot more dialogue in this past year. I think the trend in the last year has been in the right direction, but that follows a period of almost an absence in communication.

I think that the key thing that is missing, much more than throwing money at the issues, are the incentives for the private sector to both apply the results of the research and development that is here. There need to be incentives, both regulatory and economic incentives for the private sector to do the job.

I am too often discouraged a bit when I see that by the basis of the Federal procurement requirements and so forth we don't necessarily draw out the best projects. You could throw a lot of money at an energy problem, not necessarily developing the very best projects. I would rather see the incentives for the private sector to invest their own money and do the job that needs to be done in these areas. I think that by and large it can be done if the incentives are there and if a good solid technological base is established through a joint Federal-private sector program.

Mrs. SCHNEIDER. Well, let's talk, picking up on your comments, let's talk a minute about some of the incentives that you are recommending, both economic and regulatory. In terms of economic incentives, are you looking toward greater effort on the part of the Federal Government to provide something in the form of tax credits or are you thinking in terms of direct loans or subsidies that would be more on a matching basis than——

Mr. YEAGER. Well, certainly, I speak a bit from the utility industry side, which is a regulated industry and has a bit of its own unique problems. It really is not in a position to take advantage of tax credits, for example, that other industries may have. Yet 80 percent of the coal we produce is going into the utility industry. So, coal and the utility industry are essentially one and the same. If we want coal that is going to produce electricity, we have to provide some vehicle for that to happen.

Today, the industry is really in a position where every financial signal it gets is don't build anything new, maintain what you have, run it as long as possible. If we want to bring in new technology, if we want to avoid what I call short-term, short-range solutions to some of these problems, bringing in the technology that you have heard about this morning, I think you have got to provide some incentives for the people to use that. I don't think that those kinds of economic incentives are there.

I think you also need stability in environmental regulation. If you don't know what is going to happen in environmental regulation in 3 years, you build a technology and then you end up having to put a scrubber on the back end of it or build a fluid bed. There is no guarantee that I am aware of, although I think it would be the height of nonsense, but there is no guarantee that having built a fluid bed boiler, that someone may not turn around and say, that is fine but now put a scrubber on the back end of that. You have just negated about half of the benefit that you went into that project for. We have no assurance that that would not occur.

Mrs. SCHNEIDER. Based on the premise that decisions are not founded on common sense.

Mr. YEAGER. Well, we need less of an adversarial approach to solving these problems and more of a joint program. If you look around the world at the countries which are reasonably successful in this area, you find that they have a common thread and that is that there is a lot more sitting down and trying to negotiate and find a solution and plan a process rather than dealing with it in an adversarial mode.

Mrs. SCHNEIDER. OK.

Dr. Roberts, you had mentioned synfuels, and I guess that I for one am very frustrated with the situation with synfuels, the fact that we have the Synthetic Fuels Corporation sitting there. You also had discussed the involvement of the private sector. Now, the Federal Government has made this gesture to provide $15 or $16 billion to the private sector to take advantage of it for the development of synthetic fuels.

Why hasn't that taken off? Why have companies walked away from this economic incentive that the Federal Government has provided?

Dr. ROBERTS. Mrs. Schneider, that is a very important and intriguing question. I am not sure that I have the expertise to really answer it or to illuminate it. The particular technology that we are dealing with is one that is far from commercialization, is certainly not within the charter of the Synthetic Fuels Corporation, and we are talking about an R&D program much more than a commercialization program.

I am afraid the only comment I can offer to your question is that under present circumstances, private industry must judge each of the proposals that they bring to the Synthetic Fuels Corporation based on strict economic constraints. I think that will continue to be the case.

The only thing that I can say is that there has not been a good marriage of Government objectives and private industry objectives so far in the activities of that corporation, as witnessed by the lack of tangible projects.

Mrs. SCHNEIDER. Well, let me say that if we had Secretary Hodell here sitting asking questions or some other representative from the Department of Energy, right now, more likely than not having heard your testimony, they would retort by saying, well, the problem with the private sector is that here we are willing and able to provide the R&D for many of these coal projects, but we don't see the willingness on the part of the private sector to pursue the demonstration. Therefore, end of these projects. DOE seems to contend that many of the projects that all of you have mentioned here today are right at the demonstration phase and this is where you need to take up your end of the bargain.

How would you respond to that?

Dr. ROBERTS. In our particular case, we have given a good deal of thought to the demonstration of liquid phase methanol technology. Assuming that it is successfully developed to the point of being worthy of demonstration, we believe that there are several scenarios that make sense in terms of ultimate demonstration of that technology. Those scenarios all involve a demonstration plant in the 100- to 200-tons-per-day range, done in combination with a combined cycle coal gasification plant. We have had a number of discussions with potential partners in that demonstration phase already. We are optimistic that, if the technology develops to the point that we think it can, that we will be able to go forward into the next phase with a demonstration.

Mrs. SCHNEIDER. My final comment is—well, let me just commend Mr. High. I had a very fine briefing last week or a week or so ago by TVA on the various conservation/solar projects that are being undertaken, and much discussion on the fluidized bed project also, but one of the questions that I would like to raise—and I don't know if you would have the answer—are you mostly involved with the fluidized project, or are you somewhat familiar with the conservation activities of TVA also?

Mr. HIGH. Well, I have responsibility for both the in-use and supply side of the R&D and demonstration activities, so I may be able to answer your question.

Mrs. SCHNEIDER. Well, one of the points that was made at this briefing was that TVA is providing individual homeowners with a check, dollars—I don't recall if it was $450 or $540 or something like that—for their installation of various solar and/or significant conservation equipment. That is the economic incentive that TVA is providing to their users to cut down on the demand and encourage conservation.

Mr. HIGH. Well, we have a series of incentives ranging from zero interest loans to low interest loans, and perhaps the specific instance you may be referring to is the case where we try to encourage the builders in the valley to incorporate passive solar primarily. In that program, we have installed the incentive of a check, if you will, up to $1,000 for that builder to go towards building that house if he will build certain features into that, of course, meet our standards.

Mrs. SCHNEIDER. Now when I relayed this information as to what TVA was doing to someone, they came back with a rather cynical response which I would just like to check back with you. They said that the reason TVA is doing this now is because they have an overcapacity. They have a surplus of energy, and so they are really charging—despite the fact that a consumer might be cutting back on their consumption—their prices of energy are still very high because they have a surplus. Now is that so?

Mr. HIGH. Let me see if I can answer that question. That's a many-pronged question you're asking me.

Yes, we do in terms of capacity have what we would term an excess capacity in terms of the installed capacity versus what we normally would consider a reasonable reserve. That situation has been primarily economy oriented, and we have a large number of heavy metal industries that have been hurt very badly.

In regard to the fact that we still encourage conservation in solar and the other renewables, I think we view those in fact two ways: one, a capacity addition, if you will, or an option in addition to nuclear or coal-fired generation; and secondly is an energy supply, in that those systems where they are more economical for a kilowatt hour saved or one we don't have to produce——

Mrs. SCHNEIDER. Right.

Mr. HIGH [continuing]. More economical than us bringing on one of our higher cost units. It does not make good economic sense for us or our consumers to run a combustion turbine, for example, to generate a kilowatt hour if we can get that consumer to save by either turning the lights off or an incentive on home insulation. It's an economic decision and it's done on that kind of payback.

Mrs. SCHNEIDER. Good. Well, I was hoping that was the kind of a response, so I can get back to the cynic and tell him your original intent.

I would like to say that I enjoyed the testimony of each of the members here, despite the fact I had to keep running out to different hearings and other such things, but Dr. Wolfe, your testimony I thought really was extremely to the point. I hate to use the word "futuristic" because it really is a situation that you articulated that is here and now, especially with the situation going on in Iran and Iraq.

I have just completed an editorial that I am hoping the Washington Post will pick up on, on that very topic, on our failure to recognize the need to act today, but I guess my greatest frustration as a member of this committee—and I have only been here 3 years, so I can't even relate to what some of these guys feel who have been here 18 and 20 years—is that I am from my own personal perspective one of the strongest enthusiasts of getting going with coal as an option for our entire energy scenario. It is exceedingly frustrating to me that things are moving so slowly, and I am just looking at this over a 3-year time span.

I have talked to many people in the industry and in the Government area, and one of the constant messages is, "Well, part of the reason we're not moving ahead with our coal production has to do with transportation costs." Others say, "Well, it's because we need to burn coal more cleanly." There obviously seems to be a number of significant problems here, and why we don't call—and one of you had mentioned earlier today that there doesn't seem to be a focus on coal—perhaps what the coal industries ought to do is to sit down with the Government, with environmental groups that are interested in pushing for coal and other interested parties and have a coal summit where we can thoroughly analyze the problems and articulate a game plan as to how we can move toward making coal a more significant chunk in our overall energy plan.

If any of you are willing to take on the leadership for such a summit, you can count me in as one of the enthusiastic participants but I sure don't want to hear the same scenario 3 years from now that I'm hearing today, and I encourage all of you to get moving to whatever degree you can, and I'll be there to help out.

Thank you, Mr. Chairman.

Mr. BOUCHER. Thank you, Mrs. Schneider.

Mr. Lewis.

Mr. LEWIS. Thank you, Mr. Chairman.

I would like to yield just for a couple of moments to the distinguished gentleman from Virginia for an introduction.

Mr. BOUCHER. Mr. Bateman.

Mr. BATEMAN. Thank you very much, my good colleague from Florida, Mr. Lewis, and Mr. Chairman.

Unfortunately, this is one of those mornings where there has been another subcommittee and in moments I must run back to the office for something, but before doing that I want to commend the panel that is before us this morning and to especially say a word of greetings to an old friend, Dr. Wolfe, with whom I served along with you on the Virginia Coal and Energy Commission in a former day, and also to call attention in the audience this morning to a very distinguished Virginian, a very long-time and dear friend, a former Governor and a very distinguished Governor of Virginia, the Honorable John N. Dalton. I know that you join me in welcoming our former Governor to the committee, along with our good friend, Dr. Wolfe.

I wish that I did not have to depart at this point, because it is a subject in which we all have a very strong interest. With that, however, I still have to get back to the office. Thank you.

Mr. BOUCHER. Thank you, Mr. Bateman.

Mr. Lewis.

Mr. LEWIS. The Department of Energy has requested funds for the fluidized bed demonstration facility for startup and operation purposes. Why, with 5 years—it will not be operational until 1989—why is it necessary to fund that money now?

Mr. HIGH. I think the money you are referring to was put in the fiscal year 1985-86 budgets at a $30 million level for 2 years. We view that appropriation as approved by the congressional body to be applied toward the construction and startup of this facility and not the testing of it. We will be heavily involved in the construction aspects of that project toward the middle part of 1985 and during 1986 and 1987. That, in fact, is where we quite frankly need the money.

Mr. LEWIS. How much of that will you cost share with the Federal Government on the demonstration and test operations in 1988-89?

Mr. HIGH. I think what we have laid out is a pro rata share of all the parties involved in any 1 year of the expenditure rate that we would anticipate. For example, if we would spend $50 million—I believe in 1986 is what our cash flow would be—we would probably obligate $15 million of that DOE money toward a major contract, and we would expend during that year a prorated share of that compared to what all the other participants would make up toward that $50 million. If I understand your question, that's the way we would do that.

Mr. LEWIS. I see. Thank you.

Dr. Wolfe, in your written testimony that the conversion of coal to liquid fuels can be much cheaper than at current OPEC price, do you refer to water or coal/water mixtures or to coal liquefaction process?

Dr. WOLFE. Primarily it's the coal/water mixture or the coal slurry fuels. There are new technologies that are developing that utilize the coal mixing, coal/water mixture, coal/oil mixture, or blending the pulverized coal with other types of organic fluids, that tend to be a lower cost, more quickly implemented technology for certain types of industrial markets and utility markets, so I definitely believe that you can indeed achieve that sort of new form technology with a lower cost than the liquefaction processes.

Mr. LEWIS. Oh, I see. Would you say that the belief that the coal industry is a mature industry comes about from ignorance or from opposition to that fuel?

Dr. WOLFE. I think primarily, maybe a little bit of both, but I would say that some of it comes from ignorance, from the standpoint of trying to make the assumption that the coal industry is as advanced, say, as the aerospace or the nuclear industry. The coal industry over the last decade has not had a lot of funding from the Government, compared to the aerospace or defense or the nuclear programs, and it's not as sophisticated in utilizing new technologies, knowing how to go about the new technologies.

The coal industry itself has been pretty hard strapped as far as the economics of that industry over the last decade or from the beginning. They have not had the money to put into R&D because there has not been that much of a mark up on and profits in the coal industry, so I definitely believe that we need to get the message across that you cannot just develop the feasibility of the technology and then expect the industry to take it over.

I think you've got to take it a couple of steps further, more into the commercialization, and then once you've proven that technology I think that the industry will take it over. Coal/water mixture is just one of them. We did not just do it in the laboratory. We have gone ahead and done some rather sizeable commercial tests on it, and now the coal industry certainly is taking over and doing a lot of work on that. So when I said it's not a mature industry, I'm relating it primarily to taking just a big-scale type technology and saying, "All right, now it's proven. You go ahead and commercialize it." I don't think it's ready to do that.

I think Mrs. Schneider talked about the synfuels industry. That's one of the problems with the synfuels industry. We don't really have an operating plant in this country where people can go see and see it operating every day, and that's where I think we're missing the boat to some extent.

Mr. LEWIS. Well, I'm sure glad for that explanation. I asked Mrs. Schneider earlier, I wonder where we've been for the past 12 to 18 years, because coal has been around for a long, long time, and it seems like we're continuing talk about the development and the reprocessing of coal and we're always never quite there. We're always still trying to make people understand that coal is really new as far as a fuel in our country.

If you had to work within the current budget limitations from the Department of Energy, how would you assess your priorities as far as rearranging your funds?

Dr. Wolfe. Certainly I think that it is a limitation, as we all recognize, but I do believe that you've got to structure the programs so that you can get after the mobile transportation fuels. We are burning coal today. We are indeed mining a lot of coal today, and that technology maybe is not as sophisticated as it could be but we are indeed generating electricity. But we have a major additional energy need in this country, and that's for mobile transportation fuels. We don't really have an electricity shortage as much as we have an imported oil dependency based on making gasoline.

Our society depends on gasoline, and I think we ought to structure our efforts to get coal being converted more into these mobile fuels for the locomotives, the diesel replacements, the gasoline replacements, and spend more emphasis on that area than necessarily trying to improve just the combustion of it. If we can get that new industry going, I then do believe that we can have an impact on reduction in oil and keep that money here at home and use our own resources for that.

Mr. Lewis. Thank you.

Dr. Roberts, in making indirect liquefaction a viable technology, is it cost reductions in the process or rather increases in the cost of imported oil which are necessary?

Dr. Roberts. I think both are important. Certainly if we were talking about $40 a barrel oil today the way we were several years ago, the economics of many coal liquefaction processes, including indirect coal liquefaction processes, would look a lot better than they do today when we're talking about being able to purchase heavy oils in the low teens and high twenties—I'm sorry, high teens and low twenties. So there is no question that a return to the kind of pricing scenarios that we saw several years ago would improve the economics of a whole host of coal utilization projects.

On the other hand, I agree with Dr. Wolfe. I believe that coal and coal conversion and coal utilization has not been a research-intensive area for us historically. The amount of R&D dollars that have gone into various aspects of coal are very, very small compared to the amount of R&D dollars that have gone into military hardware, space exploration, electronics. I believe because of the low R&D investment there is a good deal of long-term potential for improving the economics of coal liquefaction processes and a whole host of coal utilization technologies, and we will see those improved economics if we have the fortitude to stick with, to create and stick with a stable R&D program aimed at coal.

Mr. Lewis. Thank you.

Mr. Yeager, what features of the atmospheric fluidized bed combustion process provide concern for its development?

Mr. Yeager. Concern for its development?

Mr. Lewis. Yes, yes. What are the features of it that provide the greatest concerns in its development?

Mr. Yeager. Well, of course the reason for the development is fuel flexibility and environmental control. At this stage, based on the very successful work to date, I think there are very few concerns with respect to its remaining development. It is indeed a better way to burn coal and the demonstration program, as a commitment that the utilities have made to these demonstrations, I think demonstrates the degree to which the risk has been reduced to manageable proportions.

I think this comes back to some of the discussion that has been going on earlier this morning, and that is the role of the Federal program. Here is an example of a Federal program, a Federal/private joint program which over the past 10 years has brought a technology that was a kind of an academic curiosity to the point where it is a very serious option for utility application, to the degree to which the private sector is going to be putting in about $300 million in those three demonstration projects, all brought together and led by the private sector. So I think that is a very good example to use as you examine, you know, how do you structure an overall program to bring forward new technologies in this area?

Mr. **Lewis**. Thank you.

Thank you, Mr. Chairman.

Mrs. **Schneider**. Mr. Chairman, may I ask a little followup question on that, very briefly?

Mr. **Boucher**. Yes.

Thank you, Mr. Lewis.

Mrs. Schneider.

Mrs. **Schneider**. I was just curious, as to the atmospheric fluidized bed, what are the efficiency figures that we're coming up with now?

Mr. **Yeager**. Well, in terms of the carbon utilization, the degree to which the carbon is used, our goal with the technology has always been, from a utility standpoint, to be equivalent to that of a conventional plant, at least a 99-percent carbon utilization. That kind of goal is being achieved in our test work. That originally required the use of a carbon burnup cell. Now that was an addendum, an appendage to the technology that really was not acceptable from a utility standpoint, so much of the development work over the last few years between ourselves and TVA has been to achieve those high utilization rates without going into that kind of what I would call a secondary bed.

Mrs. **Schneider**. What is the sulfur removal rate?

Mr. **Yeager**. Sulfur removal is new source performance standards, 90 percent removal or better on high sulfur coal.

Mrs. **Schneider**. What about the question of fly ash? What is the primary or what are some of the primary uses that are being made of the fly ash now?

Mr. **Yeager**. Well, I don't know that we have a lot of uses for the fly ash right now.

Mrs. **Schneider**. Well, the last time I checked they were fertilizing peanut farms and——

Mr. **Yeager**. Yes. There have been a number of tests with that but there is no major utilization program that is underway right now. Most of our programs with respect to the byproducts, both with ourselves and TVA—and Dr. High may want to add on this a little bit—have been to characterize that material and be sure that its characteristics were such that we could either dispose of it or use it in road base material or other major utilization factors of that sort.

Mrs. **Schneider**. Well, I'm getting hung up on the words "dispose of" it, because I happen to be working on some waste disposal, both hazardous and nonhazardous waste disposal legislation, and of course Dr. Wolfe was talking earlier on how he would like to see the nuclear budget exchanged with the coal combustion budget. One of the greatest criticisms of the nuclear industry is, they haven't figured out what to do with their waste.

Well, I would like to think that if I am going to be enthused about the fluidized bed process, that it would be a total process that would utilize in a very safe and productive fashion the fly ash and any other byproducts that might come along. So, insofar as the selling point is concerned, I think that that is, you know, an issue that should be addressed.

Mr. **Yeager**. I think there are two factors in the ash byproduct from the fluid bed that one has to keep in mind. One, of course, the basic material that you're disposing of there is not particularly different than you have in a conventional plant, except that the material is probably not as fine because you have not pulverized the coal in the furnace. You have a material which has less degree of surface area and probably less sensitive to leaching, but it still has the same inherent materials—all of them waste metals and so forth—that are in any fly ash, and that is a factor that we have to recognize in anything that we do with coal.

I think the key to that is the development of technologies which will extract and recover those kinds of byproduct materials that we are ultimately going to have to use in this country. That again becomes an economic question, but it is one which I think is where the development direction from a DOE standpoint ought to be going.

Mrs. **Schneider**. Have you utilized all of the data generated by the DOE utilization studies?

Mr. **Yeager**. We have certainly tried, plus a number of other studies that have been done by other areas as well. We think the DOE utilization program has been a pretty important program. We are, again, concerned that it is not one which seems to have a real vector to it in terms of continuing and developing further information.

Right now there is a major effort in the private sector. In fact, my testimony I think indicates that right now we are paying about $1 billion a year to dispose of waste products from powerplants. If we went into a major scrubber program—and I think what you have to do is compare the fluid bed with a flue gas desulfurization system—you're talking about reducing the relative byproduct waste by about a factor of three and having a dry product, in the case of the fluid bed, versus a very wet sludge material with respect to a conventional plant.

A high sulfur scrubber, for example, will produce 1 square mile of waste sludge 1 foot deep for every year it operates. That would be about a 1,000-megawatt plant, and you can see the massive land area that would be required for that. It would very quickly, I think, inundate all of the State of Rhode Island if we had it.

Mrs. **Schneider**. Please, don't even—perish the thought.

Mr. **Yeager**. So the role of the fluid bed is really, to a large extent, to reduce and make far more manageable that degree of by-product that otherwise is really in a very totally unmanageable form.

Mrs. **Schneider**. OK. Thank you.

Thank you very much, Mr. Chairman.

Mr. **Boucher**. Thank you, Mrs. Schneider, and I want to thank all of these witnesses for their very helpful testimony. I have long felt that improved coal/liquid mixtures, coal-cleaning technologies, and improved combustion systems could both help us improve energy independence and obviously improve the utilization of coal, and I am very happy to hear the comments of these witnesses this morning to that effect. We appreciate very much your being with us.

The second panel today will address fuel cell technology. We would ask at this time that the following people take their seats: Mr. William H. Podolny, vice president and general manager, Fuel Cell Operations, for United Technologies Corp.; Mr. Robert W. Fri, executive director, Fuel Cell Users Group; Dr. Bernard S. Baker, president of Energy Research Corp.—he will be accompanied by Mr. Donald R. Glenn, director of program development for Energy Research Corp.; and Mr. Fritz Kalhammer, vice president, Energy Management and Utilization for the Electric Power Research Institute.

Gentlemen, we are very pleased to have you with us this morning. The committee is going to proceed out of order for just a moment to allow Mrs. Schneider to propound several questions to the witnesses. I believe she has to leave temporarily.

Mrs. **Schneider**. Yes. Thank you, Mr. Chairman.

Mr. Fri, I regret that I cannot stay to hear all of the testimony of the witnesses but I am anxious to hear about why the peat project that was going on—sorry, I knew you would blush on this one—the peat-to-methanol project in North Carolina pulled out of the process, pulled out of the Synthetic Fuels Corporation.

Mr. **Fri**. I don't have any prepared testimony on that, Mrs. Schneider——

Mrs. **Schneider**. I didn't think so.

Mr. **Fri** [continuing]. But I'll try to answer your question.

Mrs. **Schneider**. OK.

Mr. **Fri**. The peat-to-methanol project had negotiated a letter of intent with the U.S. Synthetic Fuels Corporation in December 1982, and those are long and complex documents but from the private sector standpoint they've got two crucial features to them. One is the rate of return that is earned on the project, which I might characterize as a utility-type rate of return rather than a total private sector rate of return, and second——

Mrs. **Schneider**. I don't understand what that means.

Mr. **Fri**. Well, when I say utility rate of return, utilities tend to have rates of return geared to the fact that there is a certain amount of risk protection because of the regulatory scheme in which they are embedded, as opposed to a totally unregulated private sector venture. Obviously this or any synthetic fuels project dealing with the Synfuels Corporation is embedded in a scheme which protects it from downside risk—that's the whole purpose of the project—and therefore the returns are lower than they would be if it were a totally non-Government involved, private sector-type project. In any case, of crucial importance to the private sector is the rate of return and financial exposure in the event of abandonment or, you know, the total amount of money you have exposed at any one time in case something goes wrong—in other words, risk and return.

We negotiated an arrangment with the U.S. Synthetic Fuels Corporation in this letter of intent, which embodied a level of return and risk satisfactory, presumably, to both parties, and we were asked to go out and find a couple more equity partners, which we did. Those partners were attracted on the same risk/return calculus that had attracted the original sponsors, chiefly the Coppers Co.

This took a while—a year, in fact—and in the intervening time from December 1982 to December 1983, energy prices dropped considerably. When you crank those reduced energy prices into the arithmetic of the finances you discover, at least the sponsors felt, that it required some increase in price supports to maintain the same risk/return calculus, not to enhance it in any way but to maintain it, and so the sponsors went back to the Synthetic Fuels Corporation and asked if that could be changed.

The decision was either to go with the existing letter of intent or to reapply under the fourth solicitation, and I guess the best way to summarize it is, the Coppers Co. chiefly decided that neither arrangement was satisfactory. Both were too risky, and so they withdrew from the project and the project is now in limbo.

There was, I might add, a certain amount of publicity about the environmental questions connected with the project. I think it's fair to say that the project was nearly through a very complete environmental scrubbing and was about to get its remaining permits, and that from any objective basis this was not a serious question for the project nor a serious question that influenced the decision of the Synthetic Fuels Corporation.

Mrs. SCHNEIDER. Well, your pulling out sends a pretty strong signal, does it not, to other private sector folks who are anxious to get involved in the whole peat-to-methanol project. Seeing as how you have withdrawn because of cost overruns, isn't that something that you anticipated from the outset? Surely the market—I mean, unless the Straits of Hormuz are closed tomorrow, you're not going to see a real good price for your product tomorrow.

Mr. FRI. That's exactly right. You say cost overruns. There have been no cost overruns. The cost estimate, through repeated reviews, has remained the same for the last 2½ years.

Mrs. SCHNEIDER. But yet you said that it became more expensive.

Mr. FRI. Energy prices dropped, and so when you look at the revenues required to keep the project making a certain rate of return——

Mrs. SCHNEIDER. I see.

Mr. FRI [continuing]. And developing a certain financial exposure, and you look at the difference between that and the worst case that could happen, the worst case became worse in the year between the time the letter of intent was negotiated and we lined up the additional partners. That gap translates into additional revenue requirements, which translates into some additional obligational authority or price guarantees on the part of the Synthetic Fuels Corporation.

Mrs. SCHNEIDER. OK. Thank you very much.

Thank you, Mr. Chairman.

Mr. BOUCHER. Thank you, Mrs. Schneider.

I would remind the witnesses that their statements, without objection, will be received and made a part of the record. It will not, therefore, be necessary for you to read your entire statement. We are operating under some time constraint at this point, and we would appreciate your making your summaries as abbreviated as possible.

We will begin with Mr. Podolny.

## STATEMENT OF WILLIAM H. PODOLNY, VICE PRESIDENT AND GENERAL MANAGER, FUEL CELL OPERATIONS, UNITED TECHNOLOGIES CORP.

Mr. PODOLNY. Thank you, Mr. Chairman.

In the interest of time, I'm glad you can accept our formal statement. We are pleased to summarize it and address the fiscal 1985 budget, DOE budget for fuel cell research and development.

This committee has been a staunch supporter of UTC fuel cell programs, and the result of those programs have been rather productive. In cost-shared programs with elements of the electric utility industry, over the last year we have been able to test and demonstrate the world's first electric utility generator operating into a grid at a 4.5-megawatt level in Tokyo, and demonstrate all of the operating and installation features of such equipment and demonstrate quite clearly the efficiency and the operating flexibility of the machine, as well as the ability in New York City with the first machine to pass through a very difficult siting and environmental requirement and go through at least the process and control testing. We are still preparing to try and go operational some time this month.

In a similar cost-shared program of the gas utility industry, I thought you would be pleased to know that the first of some 46 field test units went into operation in December 1983 in Los Angeles, and at the present time, that machine has been operating 40 days continuously without shutdown. It has demonstrated its full efficiency of 40 percent electrical efficiency and approximately 85 percent of total energy recovery, delivered to a commercial site which happens to be a health spa, and further installations will be forthcoming.

In technology programs which this committee has supported, as a backdrop to our announcement and testimony last year to undertake a major commercialization effort with the private sector bearing the full brunt of that exposure, we have been able to test the first very large-scale fuel cell elements, roughly 3.5 feet on a side, and where each cell in effect generates 1¾ kilowatts. We have been able to test successfully the preliminary high-pressure, high-temperature chemical reformation of gas or naptha to hydrogen, which is a critical step, and with a program with EPRI, by the way. With DOE, we have been able to demonstrate quite a dramatic step forward in solid-state inverters which will provide for the conversion of DC to AC at these very high voltage levels and these high power levels associated with the fuel cell powerplant for the electric utility industry.

The net of all this is, if you review the present budget, a dramatic discontinuity from the level of support that the committee provided last year, and we are simply requesting that with the ongoing event of our commercialization program moving forward, this is the most improper time to discontinue the programs, which in effect is the President's request. Our testimony requests that we resume approximately the same level of funding for UTC programs in 1985 as was appropriated in 1984.

One last point, however, and it is apropros of some of the testimony at the latter part of the last session with respect to synthetic fuel demonstration plants. We do have a 4.5-megawatt fuel cell experimental configuration in the United States, in New York. We feel very strongly that in the period of time as we move forward in the commercialization program, where the private sector manufacturer will be at large risk in the early stages to finance the prototypes, utilities will be asked to provide and accept initial equipment at a substantial premium over the ultimate production price.

We will need the courage and the visibility of an operating unit and the ability to abstract serious factors of endurance, of installed cost, of reliability, that have to do with the economics of successful fuel cell powerplants. We recommended a continuance of operating the 4.5-megawatt unit in New York, including funds to provide for refurbishment so that it could be a meaningful, ongoing reference for the electric utility industry as they move forward on commercialization.

Thank you.

# PRELIMINARY
# TESTIMONY OF

WILLIAM H. PODOLNY
VICE PRESIDENT AND GENERAL MANAGER
FUEL CELL OPERATIONS, POWER SYSTEMS DIVISION
UNITED TECHNOLOGIES CORPORATION

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

MARCH 6, 1984

(AN EXPANDED AND REVISED STATEMENT
WILL BE PROVIDED TO THE COMMITTEE
WITHIN 30 DAYS)

Mr. Chairman and members of the Committee, thank you for the opportunity to address the Department of Energy's proposed FY85 fuel cell budget. This committee has shown consistent support for fuel cell research and development in recent years including support of field testing experimental 4.8 Mw electric utility systems, and similar suppport for field testing of on-site fuel cell energy service with the natural gas industry. I appear before you to appeal for continued federal support of fuel cell power plant technology evolution to enhance the probability of success of the on-going private sector investment leading towards commercialization.

I have described in prior testimony before this committee the United Technologies approach to bringing fuel cell power plants to the marketplace using the resources of the private sector. We plan to achieve an on-going production capability by the end of this decade. Our comprehensive plan to enter the marketplace with a combination of prototypes and semi-production units involves substantial private sector risk sharing by the utility industry and the manufacturer. The willingness of the private sector to assume these extraordinary technical and financial risks is based on the Federal Government continuing to play a constructive role in supporting the evolution of and advances in the technology.

The ultimate beneficiary of these efforts is the consumer of energy service based on fuel cell technology. Scarce fuel resources are converted to usuable energy with maximum conservation and minimal environmental impact. Modular and dispersed power generation which reduces planning uncertainty and construction lead time conserves scarce capital resources. As we strain to achieve commercialization as expeditiously as possible, we are convinced that the fuel cell is becoming more and more valuable to society as an extraordinary, cost effective technology to provide energy service.

The proposed Department of Energy fuel cell budget threatens to compromise the only viable effort to make fuel cells a commercial reality. Unlike other potential fuel cell manufacturers, United Technologies has demonstrated its ability to produce, design, fabricate, install and operate a number of fuel cell power plants. The promises of others to improve efficiency, reduce cost, or increase durability are not supported by any performance data from full scale components let alone complete power plants operating in the field.

An appropriate level of funding for phosphoric acid fuel cell power plant technology development at United Technologies in FY1985 is $18 million. This includes $12 million for the United Technologies electric utility multi megawatt water cooled technology programs, including fabrication and testing of experimental configurations of major components and subsystems: the reformer; the inverter; the stack; the control system; the thermal management system; and, the water treatment system. This also includes $6 million for the United Technologies gas industry multi kilowatt on-site technology development program.

The advanced research and technology development budget should include an additional $4 million for continuation of the United Technologies investigaton of phosphoric acid advanced technology. Molten Carbonate fuel cell activities at United Technologies should be funded at $5.5 million in FY85. The United Technologies program in this arena is the only one to have operated multi-cell stacks and identified potential solutions to the significant technical issues that have been defined.

The 4.8 Mw programs have become a bench mark of fuel cell viability for the electric utility industry. In order to assure the continued commitment of the utility industry to bear the major risks in bringing commercial fuel cell power plants into service, we believe that it is critical that the industry have this operating power plant available during the devlopment period of the commercial configuration as a means of providing critical operational and durability information. A decision to refurbish and modernize, where feasible, the New York City power plant would provide extended reliability, performance and endurance testing that is necessary. A program funded at $5.5 to $6.5 million per year would provide that critical data and experience from an operating fuel cell system.

United Technologies is persuing a path of fuel cell commercialization that calls on the private sector, including utilities and the manufacturer, to make a several hundred million dolar investment in prototype and semi-production fuel cell power plants during the next several years. Parties to this private-sector venture cannot be asked to accept financial and technical risks that go beyond the limits of prudent business practice. For the manufacturer and potential customers to accept these risks, a broad-band federal technology program is essential. It is time to focus federal resources on that program that has a high probability of success in acheiving commercial service. That fuel cell program which has a solid record of technical performance and an unbroken history of commitment to commercialization deserves first claim on federal resources.

Mr. Boucher. Thank you, Mr. Podolny.
Mr. Fri.

## STATEMENT OF ROBERT W. FRI, EXECUTIVE DIRECTOR, FUEL CELL USERS GROUP, ELECTRIC UTILITY INDUSTRY, INC.

Mr. Fri. Thank you, Mr. Chairman.

I am surrounded by people who are experts in the development and production of fuel cells, and so I would like to just speak to one point in my prepared remarks, and that is the utility industry's commitment to commercialization of the fuel cell.

I want to underscore that the industry's interest in the fuel cell is not simply because engineers want to develop it or suppliers want to sell it, but because the industry wants to buy it. The electric utility industry needs generating options, and this is one of the handful of new technologies that fill the bill, and there are a couple of reasons for that.

One reason is the benefits it confers on the industry. Let me quote from a talk given before the chief executives of the Edison Electric Institute by our chairman, Lee Sillin. He said:

> The key to the attractiveness of the fuel cell is that these advantages address many of the problems facing our industry today. Our industry has an urgent need for an environmentally acceptable generator that will contribute to the judicious use of fuel supplies and will alleviate the financial problems of utilities, stockholders, and ratepayers by providing an element of stability in the planning and construction cycle. The fuel cell meets these needs and its commercialization should reflect their urgency.

The other reason that the industry is looking so hard at this option is that both the EPRI technical experts and the technical experts of our own Users' Group assure us that the technology is ready to commercialize. The industry's commitment to fuel cell commercialization has been and, importantly, remains both vigorous and tangible. In the past the utility industry has contributed about a third of the development costs of fuel cells for electric utility applications, both through individual companies and through EPRI.

Today, some 56 members of the Fuel Cell Users Group of the Electric Utility Industry are actively promoting fuel cell commercialization. In the future the industry knows it must commit to several hundred million dollars to purchase initial fuel cells, and that some of those purchase costs will go to amortizing or repaying the going into business costs of the manufacturer and therefore are not entirely economic.

But our board of directors has actively considered this commitment, and believes that it is both realistic and appropriate. As a result, at their request we are starting a major effort to secure the broadest possible support in the industry for the purchase of these initial runs of fuel cells.

It is against this background that we conclude that the Department of Energy and the Federal Government have a significant role to play in continuing to support the development of fuel cells, to enhance the chances that the industry's financial commitment will pay off, as we hope it does. Conversely, the leverage of Federal funds on private commitment is very high. We think it is a good marriage, and that is why we urge that the fiscal year 1985 funding for phosphoric acid fuel cells be in the range that we have recommended, representing a continuity of the program that this committee and the Congress have approved in the past.

Thank you.

# STATEMENT ON THE FY 1985 FUEL CELL BUDGET
# OF THE DEPARTMENT OF ENERGY

Presented to the
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
of the
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. House of Representatives

ROBERT W. FRI
ADVISOR TO THE BOARD OF DIRECTORS
for the
FUEL CELL USERS GROUP OF THE ELECTRIC UTILITY INDUSTRY, Inc.
March 6, 1984

Mr. Chairman, I am Robert W. Fri, Advisor to the Board of Directors of the Fuel Cell Users Group of the Electric Utility Industry, Inc. (the Users Group).[1]

I thank you for this opportunity to present, on behalf of the Users Group, these brief remarks on the Department of Energy's FY 1985 budget for the phosphoric acid fuel cell.

First, I want to acknowledge the strong support you and your colleagues on this Committee have shown for the fuel cell over time. Had it not been for your faith and patience, this technology would not have achieved the advances of recent years.

The faith of the utility industry also remains strong, as indicated by the new resolution on "Research for Growth and National Security" (Attachment 2) passed by the full membership of the National Rural Electric Cooperative Association. The nation's utilities remain solidly committed to the advancement of the fuel cell as a powerful "tool for growth." Further indication of the broad interest in this technology is the recent formation of the Industrial Fuel Cell Association, a group established to promote the application of fuel cells in chemical and other industry plants.

I'm sorry to report, however, that the Administration has yet to acknowledge that this is not a proven technology. The appeal to DOE Secretary Hodel for greater continuity of support for this public/private partnership, from the fuel cell users groups of both the gas and electric utility industries (Attachments 3 and 4), did not produce a more balanced federal budget request for FY 85. The Department of Energy fuel cell budget request bears no relationship to the Department's existing program commitments. At $13.7 million, FY-85 requested funding is down 67.8 percent from the $42.6 million appropriated for this line item in FY 1984.

I understand that the Department of Energy has justified this cut on the assumption that the fuel cell is ready for commercialization. As you are well aware fuel cell technology still requires substantial development to achieve commercial service.

Although it has achieved many of its objectives (summarized in Attachment 5), the 4.8 Mw project in New York City is experiencing difficulties in start-up. During an attempt to produce power in late

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[1] The Fuel Cell Users Group of the Electric Utility Industry, Inc. is a four-year old organization with a membership of 56 utilities (and 8 Associate Members) spanning the privately, publicly, and cooperatively owned electric utility industry. A list of our membership is included as Attachment 1. Cumulatively, the members of the Users Group represent about 40 percent of the U.S. generating capacity. We are united in the interest of encouraging and supporting research, development, and demonstration leading to the ultimate commercialization of the phosphoric acid fuel cell power plant.

December of 1983, one of the 20 cell stack assemblies in the power plant experienced a cooling system failure which prevented the plant from becoming fully operational. A decision has now been made by the project management group (DOE/EPRI/ConEd) to replace the failed stack with a spare produced under the original power plant fabrication program.

While an attempt to operate the 4.8 Mw plant for an extended period will follow the installation of a spare stack, it should be noted that the New York site is equipped with an early cell stack configuration with limited "shelf" life. An improved cell configuration has been developed to address this known deficiency, but it came too late to be incorporated in the New York site. A sister machine of the New York power plant was built in Tokyo specifically to evaluate this improved cell technology.

I am pleased to report that the 4.8 MW unit being demonstrated by the Tokyo Electric Power Company (TEPCO) in Japan attained full rated power earlier this month and has now completed its initial validation testing. Every effort is being pursued--specifically, through an agreement executed between the United Technologies Corporation (UTC) and the Electric Power Research Institute (EPRI)--to enable participants in the U.S. fuel cell development effort to obtain full information and maximum advantage from the TEPCO program.

The technical risks so evident in these UTC demonstrations require continued federal support, but the utility industry is still preparing for commercialization.

Taking advantage of the experience in its demonstrations and incorporating advances in the technology achieved since 1976, UTC has designed and is developing an 11 MW commercial power plant. EPRI and the Users Group have participated in the conceptual stages of the design effort. Two domestic utilities have completed site-specific installation studies of this configuration. UTC plans to achieve production capability by the end of this decade. Entering the marketplace with a combination of prototypes and semi-production units will involve private-sector risk sharing by the utility industry and the manufacturer.

The Westinghouse Electric Corporation is in the technology development stage and has required performance improvements to overcome some technical hurdles that have been encountered. Nevertheless, Westinghouse is currently designing two 7.5 MW fuel power plants for installation at two host utility sites. One of these units will be electric only while the second will be used in a cogeneration application. Each plant will use gas-cooled cell stacks. The conceptual design for these plants is complete and has received a thorough review by the Fuel Cell Users Group. Delivery and installation of these units will take place in late-1986 and mid-1987.

Although commercialization support is building, the recent developments in UTC's demonstrations and Westinghouse's development program suggest that the fuel cell is far from achieving technical maturity, as the Administration would have us believe. Significant research and development work remains to be done. Accordingly, we estimate that--rather than the $7.2 million set aside for the phosphoric acid program in the Administration's FY 85 request--a prudent amount would be $25-30 million for the electric utility (multi-megawatt) activity. We understand that the on-site (40 kW) fuel cell program requires an amount comparable to that ($5 million) appropriated in FY 84, so that the entire phosphoric acid fuel cell appropriation should be approximately $30 to 35 million.

The fuel cell is worthy of continued Congressional support. A recent report by the Users Group for the Department of Energy under DOE Cooperative Agreement (#DE-FC01-82FE60018) identifies the significant advantages of this type of power production.

- With the fuel cell, utilities will be able to add increments of generation that track demand better than what is possible with larger baseload units, thus reducing the risk and financial exposure in capacity planning decisions.

- Fuel cells will go into operation sooner than units with longer leadtimes, thus improving earnings quality by limiting interest during construction.

- Operational advantages of the fuel cell include: load following, VAR control, and spinning reserve. These features combined with transmission and distribution savings due to siting near the load represent a credit of up to $125/kW of capacity.

- Cogeneration (the simultaneous production of heat and power) has a strongly positive effect on both prospective market size and share. Cogeneration credits have been estimated as high as $220/kW capacity.

- Fuel cells will be more easily sited than units with less benign environmental characteristics.

Prominent among the attractive features of the fuel cell is its minimal environmental impact, which should be of particular interest to those in Congress reviewing environmental policy and legislation. "Phosphoric acid, fuel cell power plants have low air emissions, require little or no water, and are relatively quiet," according to a report recently published by NASA for the DOE. This report, Assessment of the Environmental Aspects of the DOE Phosphoric Acid Fuel Cell Program (May, 1983 NASA #CR-168131), concludes the following with respect to air quality:

> "...The generation of electricity is responsible for the production of more particulates, sulfur oxides, and nitrogen oxides than all other stationary sources combined. In addition, about one-third of the hydrocarbon and carbon monoxide emissions from stationary sources originate from power generation systems. Even with the

> installation of the most advanced pollution-abatement equipment on new fossil-fueled power plants (particularly coal-fired), air pollutant emissions remain three to four orders of magnitude greater than those projected for similarly sized fuel cell systems. Therefore, sizable improvements in national air quality can be expected when fuel cells penetrate the energy supply market in substantial quantities. Since it is highly probable that fuel cell utilization will initially occur in areas of poor air quality (close to the load in urban areas), the air quality benefits of fuel cell systems are more likely to be focused where most needed."

If these fuel cell benefits are to be realized, developmental risks must be taken. We respectfully request a sustained sharing of these risks by the federal government.

Mr. Chairman, I thank you and the Committee for your undiminished interest in and longstanding support of this attractive technology. I encourage your continued funding for the next few critical years. I'll be be happy to respond to any comments or questions on these remarks.

Attachment 1, Page 1

## FUEL CELL USERS GROUP MEMBERS

### Federal Government Utilities

Bonneville Power Administration
Tennessee Valley Authority

### Cooperatives

Adams Electric Cooperative
Allegheny Electric Cooperative
Brazos Electric Power Cooperative
Buckeye Power Inc.
Colorado-Ute Electric Association, Inc.
Hoosier Energy Division, REC, Inc.
Lee County Electric Cooperative
National Rural Electric Cooperative Association
Seminole Electric Cooperative
Southern Maryland Electric Cooperative
United Power Association

### Municipals

American Public Power Association
Anchorage Municipal Light & Power
Arkansas River Power Authority
Easton Utilities Commission
Jacksonville Electric Authority
Lincoln Electric System
Los Angeles Dept. of Water, Power & Light
Massachusetts Municipal Wholesale Electric Company
Memphis Gas, Light & Water
Missouri Basin Municipal Power Agency
Palo Alto Electric Utility
Provo City Power
Santa Clara Electric Department
Taunton Municipal Lighting Plant

### Investor Owned Utilities

Baltimore Gas & Electric Company
Boston Edison Company
Central Hudson Gas & Electric Corporation
Central Illinois Light Company
Consolidated Edison Company of New York
The Dayton Power & Light Company
Delmarva Power and Light Company
Duquesne Light Company
Edison Electric Institute
Green Mountain Power Corporation
Hawaiian Electric Corporation

Idaho Power Company
Kansas City Power and Light Company
Long Island Light Company
Mississippi Power and Light Company
Niagara Mohawk Power Corporation
Northeast Utilities Service Company
Ohio Edison Company
Philadelphia Electric Company
Public Service Company of Oklahoma
Public Service Electric and Gas Company
San Diego Gas & Electric Company
Southern California Edison Company
Southern Company Services
Tampa Electric Company
Toledo Edison Company
Utah Power & Light Company
Virginia Electric Power Company

Foreign

Hydro-Quebec

Associate Members

Burns & McDonnell Engineering Company
Burns & Roe, Inc.
Ebasco Service Inc.
Johnson Matthey Research Centre
Kinetics Technology International Corp.
New Energy Development Organization
NUS Corporation
Stone & Webster Engineering Corporation

Attachment 2

NRECA Annual Meeting 1984

RESOLUTION NO. J-2

FROM: Research and Technological Development Committee
APPROVED BY: Resolutions Committee

SUBJECT: Research for Growth and National Security

We support a well-funded, long-range commitment for Electric Energy Systems (EES) research and development and fuel cell development. These areas have national security implications as well as the potential for providing opportunities for growth and energy self-sufficiency.

We therefore urge the Administration and Congress to provide the following:

> Minimum funding of $20-million for FY 85 for Electric Energy Systems research within the Department of Energy. EES is involved with several programs of critical national importance. Among them is the study of the effects of electromagnetic pulse (EMP) which, in the event of a strategic military weapon explosion in the atmosphere, could result in a pulse from gamma rays that could create a surge 10 to 100 times faster than a lightning stroke. Such a pulse could disrupt communications and immobilize the entire electric industry. Other EES projects which require strong support include system technologies involving improving efficiencies and reliability of power generation, transmission and energy storage, and the electric field effects of high voltage transmission lines.
>
> A five year commitment, with a minimum of $40-million for FY 85, for fuel cell research and development. The potential offered by fuel cell technology for highly efficient, dispersed electric power generation (so essential to national security) is enormous. Along with the potential economic advantages, the fuel cell has other very desirable characteristics (environmentally benign, short lead time for installation, modular design, and favorable load-following capabilities) which makes it truly a "tool for growth."

Attachment 3, Page 1

Onsite Fuel Cell
Users Group
of the Gas Utility
Industry

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Gas Research Institute
(312) 399-8235

8600 West Bryn Mawr Avenue
Chicago, Illinois 60631

August 26, 1983

The Honorable Donald Paul Hodel
Secretary
U.S. Department of Energy
1000 Independence Avenue, S.W.
Room 7A-257
Washington, D.C. 20585

Dear Secretary Hodel:

Over the past sixteen years, the electric and gas utilities, both directly and through the Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI), have invested over $150 million in phosphoric acid fuel cell (PAFC) power plant development. The private sector level of interest and financial support continues to grow as fuel cell technology comes closer to commercialization. The fuel cell program has also enjoyed broad and consistent support by Congress over the last four years. In contrast, DOE's funding support has been disappointing. As the joint DOE/industry fuel cell technology program begins the critical final step, it is essential that DOE not only request funds in its FY 1985 budget to meet its existing contractual commitments but also that DOE promptly commit funds already appropriated in the FY 1984 budget.

The electric and gas utilities are pursuing PAFC technology for two related but different applications. One application, of interest to gas and gas-electric (combination) utilities, is for small (40-300 kW) onsite generators located in commercial and multifamily residential buildings. Such plants, using pipeline gas as a fuel, could supply both electric and thermal energy, consuming no more fuel than that now required for thermal demand alone. The other application, of interest to the electric utilities, is for multimegawatt, dispersed generators located on the utility grid with the potential for waste heat recovery. These generators could use available fuels more efficiently and cleanly than any alternative peaking or load following generator.

In recognition of the potential of this option, within the past three years, over 75 electric and gas utilities have formed fuel cell users groups (The Fuel Cell Users Group of the Gas Utility Industry and The Fuel Cell Users Group of the Electric Utility Industry, Inc.) to expedite the development and commercialization of PAFC power plants (see attached member list). The development phase of the program involves joint contracts with DOE, EPRI, and GRI. The users groups provide a direct link to the electric and gas utilities which must implement the commercialization of the technology.

To resolve the question of the appropriate federal role, both EPRI and GRI adapted their fuel cell programs and funding to be consistent with the Administration's principles for federal research and development criteria. GRI, for example, assumed total funding responsibility in FY 1983 for the joint DOE/GRI 40 kW onsite fuel cell field test activities and provided 50 percent of the funds for a coordinated DOE/GRI onsite fuel cell technology development program. Therefore, we are confident that the PAFC program meets the Administration's criteria for continued DOE funding. In fact, this is evidenced by the comprehensive fuel cell R&D program DOE has planned. This Administration has signed more fuel cell R&D contracts, both in terms of dollars and numbers of contracts, than any previous Administration.

With the FY 1984 DOE budget process coming to a close and the initial planning for the FY 1985 budget being initiated, we wish to take this opportunity to discuss with you a disconcerting pattern in the DOE fuel cell program that has caused our members considerable concern during the past year. One concern is that there appears to be no link between contract funding requirements and the OMB allowance for the DOE fuel cell budget request. The other is the delay that has been experienced in contracting for new funds appropriated by the Congress. These problems not only impact the initiation and continuity of funded programs, but also impair the ability of the funding partners (EPRI and GRI) to plan and coordinate their research programs properly.

While DOE has planned and executed contracts necessary for a sound fuel cell program, there has been a breakdown between the contractual funding requirements and the budget requests for these activities. For instance, despite a cofunding agreement with GRI and a contract with United Technologies Corporation (UTC), DOE requested no funds for the 40 kW onsite technology development program in either the FY 1983 or FY 1984 budgets. Similarly, contract funding requirements for the electric utility program were $22 million in FY 1984, while the DOE budget request was for only $3 million.

Similarly, a significant portion of funds appropriated in FY 1980 through FY 1982 for new development work was not obligated for a year or more, leaving large and unproductive unobligated balances in the fuel cell program. The FY 1984 appropriations will likely authorize work beyond existing contract amounts. In view of the short time available to complete development work on the commercial prototype fuel cells, prompt obligation of these funds is important.

Attachment 3, Page 3

We hope that DOE is prepared to see the PAFC technology development through to completion in continuing partnership with industry. As an essential step in doing so, we believe that DOE should seek sufficient funds in FY 1985 to service the existing fuel cell contract program. With continued support by DOE, PAFC power plants will be commercially available within the next five years. We strongly encourage you to join U.S. electric and gas utilities and the Congress to provide adequate support for this important program. We would like to meet with you in the near future to discuss this situation and to see how we can work together more effectively.

Sincerely,

E. S. Larson
Elwin S. Larson
Chairman, Fuel Cell Users Group
of the Gas Utility Industry

Lelan F. Sillin, Jr
Lelan F. Sillin, Jr.
Chairman, Fuel Cell Users Group
of the Electric Utility Industry

Attachment

Attachment 4

THE SECRETARY OF ENERGY
WASHINGTON, D.C. 20585

November 15, 1983

Mr. Lelan F. Sillin, Jr.
Chairman
The Fuel Cell Users Group
of the Electric Utility Industry
1101 Connecticut Avenue, N.W.
Washington, D.C. 20036

Dear Mr. Sillin:

Thank you for your letter of August 26, 1983, regarding the Department of Energy's (DOE) fuel cell program and the views on the program by the fuel cell users groups established by the gas utility and the electric utility industries.

I share your views in terms of the potential benefits that could be derived from the successful development of fuel cell systems. The DOE has and will continue to place high priority on the pursuit of an aggressive fuel cell program. The fuel cell funding needs, however, must be weighed against similar requirements in other energy research and development programs to preserve program balance and against national economic priorities (which necessitate fiscal restraint in the allocation of research and development funds). In this context, difficult decisions always arise regarding relative funding priorities. While recent fuel cell budget requests by the Administration have been lower than in prior years, they have been adequate to continue fuel cell technology development and have reflected the view that phosphoric acid systems technology has been sufficiently advanced by the joint efforts of the Federal Government and the private sector that the Federal role can be diminished in this area.

Regarding your comment on the need for prompt obligation of fuel cell funds appropriated by the U.S. Congress, we believe that significant progress has been made in obligating these funds during Fiscal Year 1983. As of September 30, 1983, DOE has obligated nearly all available phosphoric acid fuel cell funds appropriated by Congress through Fiscal Year 1983. Fiscal Year 1984 Departmental obligations will be handled in an equally expeditious manner.

I appreciate your personal interest in the fuel cell program, as well as the efforts of the users group that you chair in advancing this very promising technology.

RECEIVED
NOV 28 1983
LELAN F. SILLIN, Jr.
CHAIRMAN OF THE
EXECUTIVE COMMITTEE

Sincerely,

Donald Paul Hodel

DONALD PAUL HODEL

Attachment 5, Page 1

## 4.5 MW FUEL CELL POWER PLANT DEMONSTRATION

New York City

1984 Update

Prior to 1983 the fuel cell demonstration project achieved two of its major objectives. First, it received siting authorization as a power plant in one of the most densely populated and environmentally sensitive areas in the country. Local groups, while initially expressing concern about public safety, learned more about the technology and its potential benefits and ultimately agreed to the facility's construction. Second, the plant was factory fabricated and installed on site by a utility using traditional methods.

Also prior to 1983, this first-of-a-kind power plant experienced extraordinary test requirements mandated by local authorities and damage to three key components due to material failure, water freezing after required hydro testing and loose insulation deflecting the flame of two start-up torches directly onto key elements in the fuel processing system. These difficulties resulted in about 2-1/2 to 3 years of delays. However, these obstacles were overcome through modified designs, new materials, revised testing procedures and other changes and innovations.

During 1983 the most important operational step toward producing electricity took place. This was the completion of the Process and Control Test, or PAC Test. The purpose of this test is to prove out the processing of the fuel into the hydrogen rich gas required by the fuel cells. It is also during PAC Test that all of the auxiliary systems and components are exercised for the first time and operated as a unit. Additionally, it provides the opportunity to cycle the fuel processing system several times, thereby verifying the repeatability of the system to perform properly. Stable operation of this system was achieved on June 8 and the PAC Test was successfully completed on June 17, 1983.

Another major step accomplished during 1983 was successful testing of the Power Conditioning System. This system converts direct current electricity into the alternating current used by most utility consumers. This accomplishment was preceeded by the usual difficulties encountered in debugging electrical devices of new designs, such as component failures, undersized electrical components, and electrical interference in logic circuits. Thermal stability tests and a 100-hour operational test successfully culminated this test activity in March, 1983.

After completion of these tests the fuel cells were installed and the production of electricity was attempted in late December 1983. Data collected during this attempt indicates that one fuel cell stack assembly has been rendered unuseable due to an internal water leak. Data also suggests that some of the 5-year old first generation fuel cell stack assemblies, while operable, are showing signs of "old age". The next attempt to start-up has been postponed while this situation is studied and evaluated. The next attempt may not begin until April 1984.

A similar 4.5 MW power plant from the same manufacturer but using improved fuel cell stack assemblies benefitted from the difficulties encountered in New York City and is now operating as a test unit in Tokyo, Japan, just three years after it was ordered. Operating data from this unit may be made available to U.S. utilities later this year.

It is important to note that much learning has already been attained from the New York demonstration. As significant as these technical achievements are, however, the production of electricity is still the goal in New York City. Its operation is expected to be useful for establishing utility confidence in the technology base and utility willingness to proceed with the high risk commercial prototype power plant purchases.

Achieving our mutual goal of commercialization of this technology still requires costly fabrication, construction and start-up testing of the first-of-a-kind commercial prototype power plants. The federal support has been instrumental in the development of the technology base. Prior to the private sector acceptance of the commercialization risks and costs, however, the technology programs must achieve their cost reduction goals and key component and system tests must be conducted.

Mr. LEWIS [acting chairman]. Thank you, Mr. Fri.
Dr. Baker.

## STATEMENT OF DR. BERNARD S. BAKER, PRESIDENT, ENERGY RESEARCH CORP., ACCOMPANIED BY DONOLD R. GLENN, DIRECTOR, PROGRAM DEVELOPMENT

Dr. BAKER. I appreciate the opportunity to speak before this committee. I am president of Energy Research Corp., a Fluor Co. I have been continuously active in the fuel cell field since 1959, and Energy Research Corp. has been active in the field since 1970.

ERC is participating in the development of both phosphoric acid and molten carbonate fuel cells. In the phosphoric acid fuel cell area, we have recently developed a fully automatic, small portable powerplant for the U.S. Army. This unit, methanol fueled, 3 kilowatt in size, is a silent powerplant whose efficiency is the highest ever achieved for the Army. It is about 300 percent more efficient than comparable size conventional generators. We have also pioneered the development of the air-cooled phosphoric acid fuel cell which has been licensed to Westinghouse Electric Corp. for development of a more advanced, reliable, multimegawatt powerplant for use by the electric utilities.

Today, however, I would like to speak about the molten carbonate fuel cell system and more specifically about our direct fuel cell, which is a carbonate fuel cell with internal reforming. This advanced type of fuel cell will be the simplest and most efficient of any electric power generator fueled by fossil fuels. Overall efficiencies of 60 percent are obtainable. Unlike the phosphoric acid fuel cell, this fuel cell system requires no external reformer and therefore about 35 percent of the plant equipment is eliminated.

ERC has been developing this technology for the past 3 years with Department of Energy, EPRI, GRI, and internal funds, and has clearly demonstrated technical feasibility. Under our DOE program we have operated cells for 4,000 hours directly on methane fuel. Under an EPRI contract we have designed, together with Fluor Corp., our parent company, a 2-megawatt direct fuel cell system which would be truck transportable, have a 6,500 BTU per kilowatt hour heat rate, be sitable anywhere, cost $1,300 a kilowatt, and deliver power from $6 per million BTU gas for 8.5 cents a kilowatt hour. In my written testimony I quote both Government and industry experts who share my enthusiasm for this approach.

This important fuel cell development comes at a time when there are serious concerns about nuclear and conventional coal-powered plants. Funding is needed over the next 3 years to further develop the technology and test the full size, direct fuel cell basic power module of about 50 kilowatts, which can be the basis for a variety of small and large natural gas fuel cell powerplants and the foundation for building a coal-fired station. Funding of $3 million is needed in 1985, $4 million in 1986, and $5.5 million in 1987 to achieve this development goal at ERC. Private funding of about $4 million will be available to supplement this effort.

Beyond 1987, additional substantial funds will be needed for powerplant prototypes in the 2- to 10-megawatt size range. Whether a financial role on the part of Government is desirable or necessary at that point must be determined later. Now, however, it is essential that the basic building blocks of this exciting technology be nurtured by Federal R&D expenditures.

To accomplish this progress, ERC requests that the 1985 molten carbonate fuel cell budget be increased by $1.3 million above the 1984 level of congressional appropriation to further the direct fuel cell development described today. This project could be the basis for a whole new power generation industry with substantial domestic and export markets. It can further reduce dependence on foreign oil supplies and reduce the cost of electricity to all Americans.

The patience and steadfast belief of the Congress in encouraging the Federal program by your continued upgrading of the recent administration's budget requests, along with our industrial agency's funds, are responsible for bringing this superb technology to a state of progress somewhat ahead of the best technical projections of only a few years ago.

Thank you.

[The prepared statement of Dr. Baker follows:]

ENERGY RESEARCH CORPORATION

Statement of Bernard S. Baker
President
Energy Research Corporation

U.S. HOUSE OF REPRESENTATIVES
Committee on Science and Technology
Don Fuqua, Chairman
Subcommittee on Energy Development and Applications
Hearings on Fiscal Year 1985 Authorization
For The Department of Energy's Fossil Energy R&D Program

March 6, 1984

ENERGY RESEARCH CORPORATION

BERNARD S. BAKER, PRESIDENT
ENERGY RESEARCH CORPORATION

Good Morning. I am Bernard S. Baker, President of the Energy Research Corporation (ERC), a subsidiary of St. Joe Minerals Corporation, a Fluor Company. I have a Ph.D. in Chemical Engineering and have been continuously active in the field of fuel cell R&D since 1959. Thank you for the opportunity of presenting my views on the DOE Fuel Cell Program's FY 1985 Budget with specific reference to the Direct Fuel Cell (DFC) portion of the Molten Carbonate Fuel Cell line item for which we are seeking an additional $3 million funding.

ERC was founded in 1969 to develop, manufacture and sell energy conversion devices, including batteries and fuel cell systems. With these functions as the entire purpose of ERC, the company has assembled one of the largest teams of electrochemical technology-trained researchers, engineers and support staff, located in the U.S. Headquartered in Danbury, Connecticut, our 140 employees have made ERC a major factor in developing more energy-efficient power conversion and storage equipment.

ERC serves both private and governmental clients; among these are the National Aeronautics and Space Administration, Electric Power Research Institute, Gas Research Institute and the Departments of Defense and Energy. These agencies are the primary sources of funding for research and development on fuel cells.

The progress in fuel cell development is very good. The phosphoric acid fuel cell is progressing from water cooled plants to the less complex air-cooled system. In the longer term the molten carbonate fuel cell will yield more efficient and even simpler plants than the acid fuel cell.

In reaching the present status I would like to summarize, briefly, the important progress made by ERC in both fuel cell technologies and describe in greater detail our direct fuel cell. This latter system will provide the highest electrical efficiency power system ever devised for use with fossil fuels.

## PHOSPHORIC ACID FUEL CELLS

The PAFC program at ERC consists of two fundamental efforts, the development of small stand-alone systems (up to about 10 kW) and a technology support element to provide electric utility/industrial-sized stacks, the basic element in a fuel cell system. In the first category, ERC has developed and delivered several military-type units at the 1-1/2 kW size for test and evaluation. We are presently testing the first fully automatic PAFC plant, at the 3 kW level, prior to shipment to the Army next month. A 5 kW and a 20 kW system are being built this year. These units are air-cooled, operate at ambient pressure at 375°F, using a methanol fuel. While currently directed at the military for portable, silent, high efficiency power needs, these plants may serve special residential and small commercial applications when mass-production-induced, cost-competitive manufacturing is attained. These air-cooled systems have superior low temperature starting, rapid start-up (15 minutes), and provide warm air (reject cooling) for space heating or process heat in a cogeneration mode.

Under a teaming agreement with Westinghouse Electric Corporation, our fuel cell licensee, ERC is providing large stack technology for electric utility and industrial fuel cell powerplants. Using ERC air-cooled stack technology, a high efficiency, high pressure multimegawatt powerplant is being developed which is considerably simpler and intrinsically more reliable than the earlier water-cooled plants. ERC is working with Westinghouse to solve some of the remaining technology problems associated with this advanced type of phosphoric acid fuel cell powerplant which we believe will become a reliable standard for the electric utilities at a time when these utilities are experiencing problems with nuclear powerplants and there is concern over acid rain from coal fired generating plants.

## MOLTEN CARBONATE FUEL CELLS

The Molten Carbonate Fuel Cell (MCFC), a second generation technology, is the most attractive power conversion option on the horizon for both industry and utility markets. With a laboratory verified efficiency of 60% for the fuel-to-electricity conversion and additional energy available for the use as high quality (1150°F) heat by-product, this system has captured the interest of the potential end-users as well as the fuel cell R&D community both in the U.S. and elsewhere, in addition to your Subcommittee.

Generally considered a "1990" technology, several firms are actively pursuing research and development in this area. ERC, as one of the leaders since 1976, has already experimented with a significant refinement in the basic carbonate fuel cell process with a very successful outcome which we call the Direct Fuel Cell. Before I describe this development let me first describe the basic molten carbonate fuel cell.

This fuel cell operates at about 1150°F and the high temperature allows the electricity producing reactions to take place without using expensive catalysts. The electrolyte used is a molten salt, alkali metal carbonate, which can be operated at moderately high temperatures but ambient pressures. In general, the basic efficiency of this cell is higher than that of the acid fuel cell because the electrochemical reactions are more reversible. The concept is not new. It was developed first in Holland in the early 1950's but other fuel cell approaches have held the limelight until recently.

The conventional MCFC requires either of two fuel streams for operation, hydrogen or carbon monoxide. Hydrogen or carbon-rich fuels, i.e., natural gas, methane, methanol, provide the basic chemical constituents and when reacted under the influence of heat and steam in a reformer or gasifier, these streams are produced. In a system containing an external (to the fuel cell) reformer, however, additional costly peripheral equipment must be included, such as heat exchangers and the reformer itself. ERC's Direct Fuel Cell (DFC) eliminates this complexity and therefore, increases system efficiency while reducing its cost.

## DIRECT FUEL CELL STATUS

During the past 3 years, ERC has designed and tested a molten carbonate fuel cell which can operate directly on fossil fuels. So far methane and methanol have been successfully tested. By this means, ERC can eliminate the costly and complex fuel processor, i.e., hydrogen generator previously required. This eliminates about 35% of the plant equipment, simplifies the plant and reduces its cost. Moreover, since the fuel cell waste heat is now used directly in breaking down the fossil fuel, these new direct fuel cells are very efficient. Theoretically, the direct conversion of natural gas in these fuel cells could take place at 100% efficiency because there is no entropy loss for the reactions. In practice, however, we would consider 60 to 65% efficiency a major technical success for economically viable powerplants.

**ENERGY RESEARCH CORPORATION**

In 1983, ERC conducted several major tests under DOE and EPRI projects. The direct fuel cell was demonstrated with methane fuel in pilot size cells for 4000 hours continuous testing. Conversion of methane into hydrogen under cell operating conditions was complete.

In related tests, a 7000 hour experiment was successfully completed on a new noncorroding current collector material. New catalysts for methane conversion were also demonstrated.

Cell components were scaled to full size cells without major difficulties.

The bulk of the materials used in ERC's Direct Fuel Cell are available in abundant quantities in North America and no precious metals are required.

During 1983, a plant design for EPRI based on this approach was completed by ERC together with its parent company, Fluor Corp., which indicated a 6500 Btu/kWhr Direct Fuel Cell Plant was feasible. This was a simple atmospheric pressure plant with no fuel processor and only one heat exchanger. Such a plant is about 40% more efficient than an acid fuel cell plant. This high efficiency would mean considerable cost savings to the consumer and considerable operating advantages to the electric utility. Because the powerplant uses fossil fuels directly, it will have fewer parts and subsystems than those fuel cell plants using external fuel processors to produce hydrogen.

The powerplant cost of the design study size of 2 MW would be $1300/kW and produce electricity at about 8.5 cents/kWhr using natural gas at an estimated cost of $6/MMBtu. Using the prevailing costs of natural gas, electricity costs of 5-6 cents/kWhr would be possible if these plants were available today.

This entire plant could be built on truck transportable skids and would occupy one-tenth of an acre!

Since these plants produce no pollution, they could be sited almost anywhere and deliver safe, environmentally acceptable power in any size plant required by the utility.

Applications for this Direct Fuel Cell system are numerous. In addition to the above mentioned EPRI electric utility system, ERC designed a 50 kW natural gas fueled, on-site system with an overall efficiency of 55%. This unit is half the size of the corresponding 40 kW acid fuel cell system and will produce electricity for about 40% less cost.

Finally, ERC has begun to look at coal fueled power units where the impact of the Direct Fuel Cell on coal gasifier design could be substantial. The latter results from the ability of the Direct Fuel Cell to use methane and carbon monoxide as well as hydrogen fuel. Thus the coal gasifier and, hence, overall powerplant will be more efficient.

ERC, in carefully moving the Direct Fuel Cell through these early, critical concept feasibility and technical innovation phases, is now more confident that this approach can be more aggressively advanced.

(The figures at the end of this paper convey some of the characteristics discussed above.)

## DIRECT FUEL CELL - NEXT STEPS

The progress to date is very significant, but not complete. There are still several major milestones ahead that will build on the successes to date towards integration of the single cells into a multicell arrangement (called a short stack) to test cell assembly techniques, and their impacts on gas flows, distribution and operating limitations. The Direct Fuel Cell approach must be evaluated in stacks of at least ten cells to verify the full range of thermal operating conditions and finally scale up to taller stacks, 50 to 100 cells, is needed to create a basic building module for powerplant construction. Material selections to lower the capital costs without excessive corrosion or deterioration from trace contaminants customarily found in the various gaseous fuel sources need to be evaluated. Additional endurance testing is also required.

The next three years will yield these answers. While there is always some chance for failure in any R&D pursuit, I believe the risk of this has been minimized by ERC's guarded and conservative thoroughness thus far in the design of our tasks, and the excellent leadership provided by DOE and ANL, its technical manager, and our industrial supporters, EPRI and GRI. To date, this has been by far, the smallest fuel cell program funded by DOE, but clearly one of the most successful. I quote from the following experts' comments:

Mr. Ed Gillis, Project Manager, EPRI, Energy Management Utilization Division, perhaps the electric utility industry's leading technical expert on fuel cells, states in EPRI report EM-3307 entitled, "Assessment of a 6500-Btu/kWhr Heat Rate Dispersed Generator" referring to the ERC Direct Fuel Cell:

"This preliminary assessment shows the internal-reforming MCFC to be a highly efficient and potentially economical candidate for dispersed generation. ........ It is also encouraging that the cost, performance, and durability goals for the fuel cell stacks, as identified in this study, appear to be less challenging than for other fuel cell systems that EPRI is developing; hence, the probability of success is improved."

Dr. John Ackerman, Manager Electrochemical Research at Argonne National Laboratory and a leading technical expert in this field, as reported in "Coal Technology Report," February 6, 1984, in an article on molten carbonate fuel cells:

"A twist on the MCFC design is being studied at Energy Research Corporation. Scientists there are looking at direct-fueled cells. These cells reform the fuel internally, eliminating the need for a fuel processing unit, which precedes the fuel cell stack in the phosphoric acid systems. Ackerman says this type of fuel cell could offer several advantages, the most prominent being lower capital costs. The system would be simpler, giving more power per unit of fuel cell."

I believe this Direct Fuel Cell technology can lead to a new generation of super efficient powerplants which initially will be fueled with natural gas and eventually fueled with coal and other renewable fuels. This technology comes at a time when fuel costs are high in real terms and when the power generation industry is besieged by problems with nuclear power, concerns about acid rain, and the long-term effects of carbon dioxide in the atmosphere. The power produced by this direct fuel cell powerplant would be clean, safe and inexpensive. The carbon dioxide released to the atmosphere would be greatly reduced, almost halved, because of its high efficiency.

Funding is needed over the next three years to develop the technology and test a full size direct fuel cell basic power module of about 50 kW, which can be the basis for a variety of small and large natural gas fuel cell powerplants and the foundation for building a coal fired station. Funding of $3 million is needed in 1985, $4 million in 1986 and $5.5 million in 1987 to achieve this development goal at ERC. Private funding of about $4 million dollars will supplement this effort.

Beyond 1987, additional substantial funds will be needed for powerplant prototypes in the 2-10 MW size range. Whether a financial role on the part of the Government is desirable or necessary at that point must be determined later. Now, however, it is essential that the basic building blocks of this exciting technology be nurtured by Federal R&D expenditures.

To accomplish this progress, ERC requests that the 1985 Molten Carbonate Fuel Cell Budget be increased 1.3 million dollars above the 1984 level of congressional appropriation to further the Direct Fuel Cell development described today. This project could be the basis for a whole new power generation industry with substantial domestic and export markets. It can further reduce dependence on foreign oil supplies while reducing the cost of electricity to virtually all Americans.

The patience and steadfast belief of the Congress in encouraging the Federal program by your continued upgrading of recent Administration's budget requests, along with our industrial agency's funds, are responsible for bringing this superb technology to a state of progress somewhat ahead of the best technical projections of only a few years ago.

Thank you.

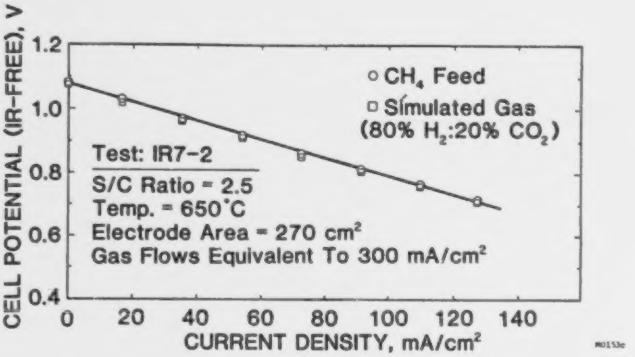


FIGURE 1. METHANE AND EXTERNALLY REFORMED GAS PERFORM THE SAME IN THE ERC DIRECT FUEL CELL

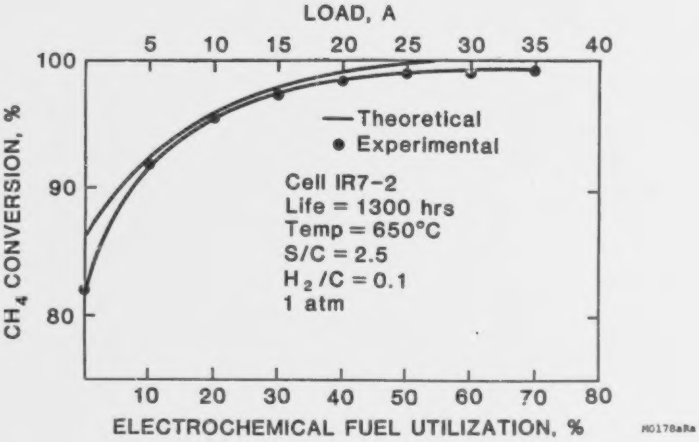
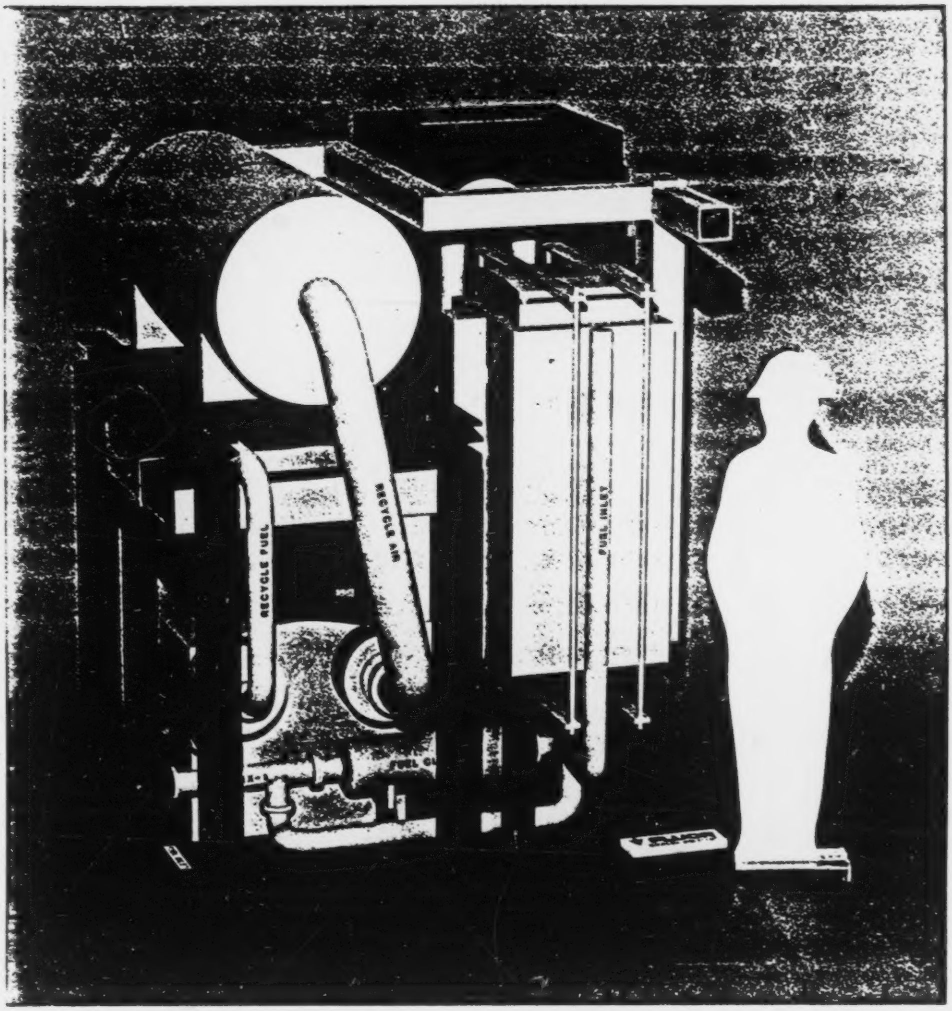


FIGURE 2. CONVERSION OF METHANE IS COMPLETE IN DIRECT FUEL CELL


RECYCLE FUEL
RECYCLE AIR
FUEL INLET

P0644

FIGURE 3. 50 kW DIRECT FUEL CELL ON-SITE INTEGRATED ENERGY SYSTEM IS COMPACT

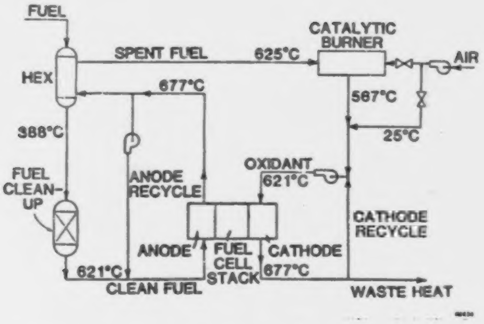

FUEL
HEX
SPENT FUEL
625°C
CATALYTIC BURNER
AIR
677°C
567°C
388°C
25°C
FUEL CLEAN-UP
ANODE RECYCLE
OXIDANT
621°C
CATHODE RECYCLE
ANODE
FUEL CELL STACK
CATHODE
621°C
677°C
CLEAN FUEL
WASTE HEAT

FIGURE 4. SCHEMATIC OF SIMPLE DIRECT FUEL CELL DISPERSED GENERATOR DESIGNED FOR EPRI

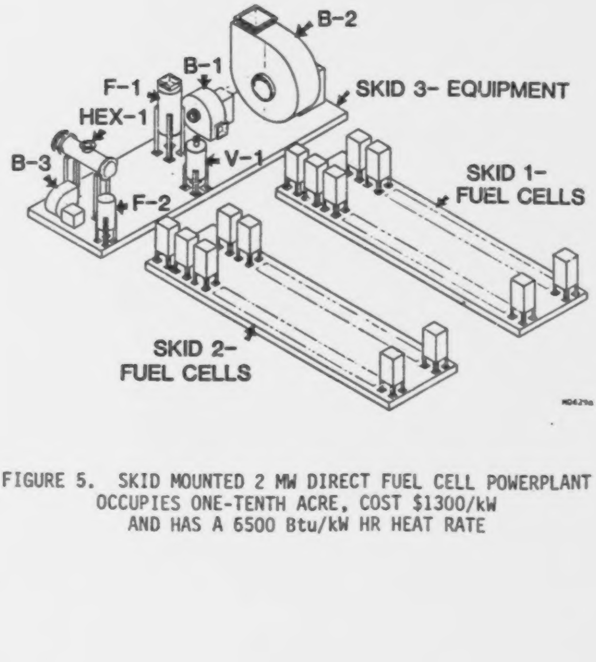

B-2
B-1
F-1
SKID 3- EQUIPMENT
HEX-1
V-1
B-3
F-2
SKID 1- FUEL CELLS
SKID 2- FUEL CELLS

FIGURE 5. SKID MOUNTED 2 MW DIRECT FUEL CELL POWERPLANT OCCUPIES ONE-TENTH ACRE, COST $1300/kW AND HAS A 6500 Btu/kW HR HEAT RATE

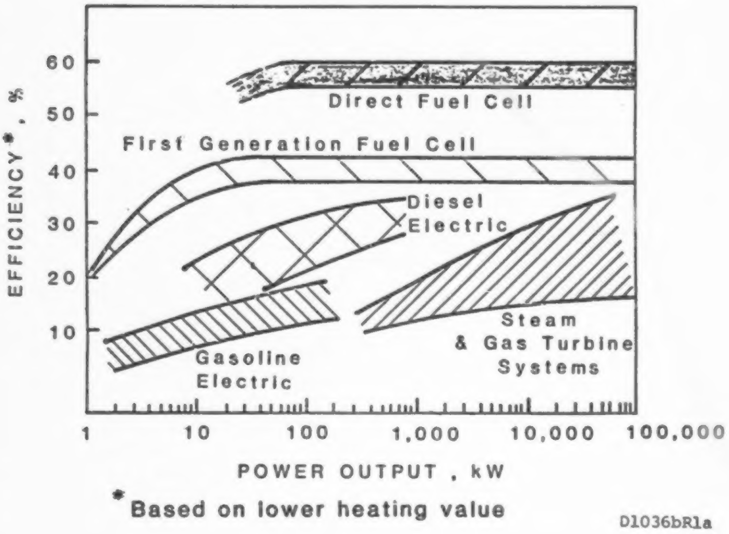


FIGURE 6. EFFICIENCY COMPARISON OF THE DIRECT FUEL CELL WITH CONVENTIONAL FUEL CELLS AND OTHER ELECTRIC POWER GENERATORS

Mr. LEWIS. Thank you, Dr. Baker.

Do you have testimony, Mr. Glenn?

Mr. Kalhammer.

Mr. KALHAMMER. Pardon me?

Mr. LEWIS. Continue, please.

## STATEMENT OF FRITZ KALHAMMER, VICE PRESIDENT, ENERGY MANAGEMENT AND UTILIZATION, ELECTRIC POWER RESEARCH INSTITUTE

Mr. KALHAMMER. My name is Fritz Kalhammer. I am vice president of the Energy Management and Utilization Division of the Electric Power Research Institute [EPRI], where fuel cells are among my areas of responsibility. I am not going to read my entire testimony but rather summarize the front part.

I would like to repeat in perhaps somewhat other words the statement from Mr. Fri, who attested to the importance that the fuel cell is being given by many electric utilities in this country, many of which support the program at EPRI. At EPRI we have been involved in fuel cell development, research and development, for the last 10 years, in a program in which we have already invested $70 million to date. Our conviction that the fuel cell is indeed an extremely appropriate generating option for the electric utilities—clean, modular, meeting the requirements for planning flexibility and for a clean environment—is attested to by the fact that we have earmarked another $75 million for the next 5 years in our R&D program to be spent on fuel cell development and commercialization.

This recognizes the fact that the fuel cell could become available, if vigorously developed and brought to full commercial status, in the next few years. It also recognizes the fact that there is some more advanced fuel cell technology available that is also under development in the programs of the Federal Government and EPRI that can have yet greater benefits in terms of yet higher efficiency and greater flexibility to operate on all kinds of fuels, including coal.

The Department of Energy and the Federal Government, really first through ERDA and then through the Department of Energy, has been a partner with EPRI in fuel cell development for about 8 years now. This joint effort to move this exciting technology forward started in 1976 when DOE, United Technologies, and then Consolidated Edison of New York and EPRI joined in the 4.8 megawatt demonstrator project. Although this project has taken somewhat longer than we all estimated in the beginning, I think it has been successful in showing that a fuel cell can in fact be sited in a constrained urban environment. Most of the operating features and the plant features of the fuel cell have been shown to operate as designed and as constructed, and we fully expect that this machine will generate power in the first half of 1984.

Beyond this joint project, we have teamed up with the Department of Energy in a number of other fuel cell activities. In fact, you can say that every fuel cell, significant fuel cell activity in this country is really part of a closely coordinated national effort in which the Government plays a major role. These efforts include sizable programs to move the technology along from the current technical feasibility status to that of commercial feasibility, which includes then an upgrading and an improvement of the technology in an effort to reduce costs. It also includes some work on more advanced fuel cell concepts which I referred to a moment ago.

We believe that this involvement of the Federal Government now through the DOE program has been very successful. Mr. Podolny has already alluded to some of the technical successes. We believe what is now needed is a determined effort to bring the technology from the current state of technical feasibility to that of commercial readiness, which still requires significant funds for development.

While we are EPRI certainly believe in the need for fiscal responsibility on the part of the Government and an effort to limit budgetary expenditures, we do feel that the radical decrease in funding as it would be now proposed by the DOE budget is inappropriate and would preclude success with the first really new generating technology that has come along in this country or anywhere in a long time, so we would basically propose that the funding levels that this committee allocated a year ago for the previous year's budget would be continued over into fiscal 1985.

I have in my testimony given a number of funding proposals for various aspects of the DOE program that I feel would make it the continued mainstay and partner of the private sector efforts to move the technology to the commercial readiness phase and to keep open the technological options for yet greater advances in fuel cell technology and applications.

I believe I would like to conclude my testimony with these words and also with expressions of gratitude to this committee, which has been so supportive of the fuel cell in the past.

[The prepared statement of Mr. Kalhammer follows:]

# STATEMENT OF FRITZ R. KALHAMMER
VICE PRESIDENT, ENERGY MANAGEMENT AND UTILIZATION DIVISION
ELECTRIC POWER RESEARCH INSTITUTE
to the
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
March 6, 1984

Mr. Chairman and Members of the Subcommittee:

I am Fritz R. Kalhammer, Vice President of the Energy Management and Utilization Division for the Electric Power Research Institute. On behalf of EPRI, I would like to thank you for this opportunity to provide you with our thoughts regarding fuel cell power plants and the programmatic issues that are related to their development and commercial use.

The electric utility industry's interest in fuel cells as a highly efficient and clean method of generating electric power originated in 1971 when nine utilities and United Technologies Corporation initiated the FCG1 program. In 1973, the industry transferred the responsibility for fuel cell research and development to EPRI. I became personally involved in the effort at that time and have remained involved through the present. Within EPRI, the fuel cell program is a major effort. Through 1983, EPRI expended over $70 million in support of fuel cell RD&D. Furthermore, EPRI has budgeted $75 million to support the continued development and commercialization of fuel cell power plants during the 1984 to 1988 time period. Approximately 80% of EPRI's fuel cell budget has focused on expediting the commercialization of phosphoric acid fuel cell power plants. The remainder has addressed advanced fuel cell concepts such as the molten carbonate and solid oxide fuel cells. This allocation of funds recognizes several facts, namely:

- the utility industry's need for a fuel flexible, highly efficient, environmentally benign and modular technology; this need exists today and will become urgent in the late 80's and early 90's when the present surplus generating capacity is used up;
- phosphoric acid fuel cell power plants could be available to meet this need if their development is completed and the commercialization process expedited during the next years;
- advanced fuel cells hold great promise for the mid- to late- 90's but cannot reasonably be expected to be successfully developed before then.

Since 1976, EPRI has worked closely with the Federal Government's energy R&D conducted under the auspices of ERDA and now DOE to advance the technology of fuel cells. Our first joint activity, the 4.8 MW fuel cell demonstration in New York City, was put in place in June 1976. While that project is taking longer than originally estimated to reach the point of producing power, I believe the project has already yielded important benefits: it has verified that fuel cells can be sited in an environmentally and physically constrained urban environment, it has demonstrated most aspects of operating and maintaining such power plants, and it has focused the interest of more than 60 electric utilities on this new technology. Working as a team comprising the developer, the host utility, DOE and EPRI, we have identified and corrected deficiencies, and we fully expect to produce power in the near future.

Since the initiation of the 4.8MW project, EPRI and DOE have carefully coordinated all fuel cell activities. These have included:

- a program with United Technologies Corporation to complete the development and verification of the improved fuel cell components that are required to move from the 4.8MW demonstration to a cost effective commercial prototype;

- a similar program with Westinghouse to develop the air-cooled phosphoric acid power plant and achieve durability of the major subsystems;

- coordinated projects to develop a high-efficiency molten carbonate fuel cell technology.

We are proud of the excellent coordination that we have been able to maintain with the Government during the past eight years, and we look forward to continued cooperation in the future. There is no question that the sustained, substantial R&D program of the Federal Government was a major factor in achieving the impressive progress in fuel cell technology during the last 8-10 years.

We believe that, with a determined cooperative effort over the next several years, the basis for a commercial fuel cell power plant technology can be established successfully. EPRI supports the efforts of the Congress and the Administration to reduce deficits. However, we are concerned about the level of funding that has been requested for FY85 to support the continued development of the electric utility phosphoric acid fuel cell. The recommendations that follow are presented in the sense of proposing a higher priority for this program within the DOE budget request as a whole. Specifically, although the phosphoric acid fuel cell can now be considered a technical success, we still must complete the R&D needed to yield a cost-effective, reliable power plant before we can expect the private sector to move the technology into the market place. The coordinated programs now in place are designed to yield the necessary results over the next two to three years. However, this requires a FY85 DOE funding level of $27 million for the electric utility phosphoric acid activities (including $1-2 million for the continued support of the 4.8 MW demonstrator) which, when combined with the needs of the on-site fuel cell, would result in a phosphoric acid fuel cell funding requirement of a little over $32 million. EPRI has agreed to do its part in the commercialization of fuel cells. In fact, our funding for phosphoric acid fuel cells is due to increase from $5 million in FY84 to $7 million in FY85, to $16 million in FY86. This commitment assures that by FY86 a series of RD&D activities which in the past have been heavily supported by DOE will be yielding the results on which private-sector commercialization efforts can be based.

We also believe that the DOE budget for the molten carbonate fuel cell and other advanced concepts should at least be maintained at the FY84 level of $10-11 million. The molten carbonate and the solid-oxide fuel cells offer the promise of generating electricity from a wide range of fuels at higher efficiency than is possible with any other type of power plant. Because the technical risk of this R&D is high and development is not likely to be complete for another 10 years, DOE's continued support of this effort is both appropriate and essential.

Mr. Chairman, this concludes my remarks. I thank you and the Committee for your previous efforts on behalf of this unique technology. And I thank you for the opportunity to present my thoughts.

Mr. Lewis. Thank you, Mr. Kalhammer. I would also like to thank all four of the witnesses for the brief testimony.

Mr. Podolny, briefly, what risks both financially and technically are the utilities and the manufacturers prepared to take to commercialize fuel cell technology?

Mr. Podolny. Well, the present plan has a significant risk to the manufacturer in the first phase because it bears the burden of financing the definition of the product and the development of the product through the delivery of prototype. Utilities bear the burden of assuming a premium price unit even though it would be sold at firm fixed price against a warrant of some performance and some durability.

The real issue would be whether we would be able to find in this small, relatively small lot of approximately 250 megawatts, sufficient operating and installed cost experience that would say we have convinced both the manufacturer and the utilities that we would be able to move forward in future production. The risk to the manufacturer throughout the whole is really the full burden of contingency risk. The risk to the utility essentially would be the risk of installation costs and operating costs being greater than what may have been originally estimated.

Mr. Lewis. When do you expect to be able to make commercial offerings for both utility-size and on-site phosphoric acid fuel cells?

Mr. Podolny. With the large-scale electric utility it is imminent within the next several months, this year. We have a contractual obligation with the gas utility industry, with Gas Research Institute, and we must submit a full commercialization venture proposition, manufacturer to utility, at a point in time which is really tied to the experience we get with the 46 powerplants which are being field tested. My estimate would be late 1985 for the on-site machine.

Mr. Lewis. What is the status of the 4.8 megawatt fuel cell plant at Tokyo Electric in Japan?

Mr. Podolny. That powerplant went operational last April, and as of February this year we have accumulated I think about 300 hours total and it has gone to full rated power at full rated efficiency. The Tokyo Electric Power Co., has commissioned us to refurbish the balance of plant, add some redundancy, and in the latter part of May they mean to operate the powerplant to generate reliability and maintenance data for reference to the commercialization configuration.

Mr. Lewis. You do have access to a great amount of data being generated by the Tokyo plant?

Mr. Podolny. Sir, that powerplant is designed by Americans, manufactured by Americans, delivered and in effect mostly operated by Americans, and all of the data becomes not so much our property but completely available for our use without constraint.

Mr. Lewis. I see.

Mr. Podolny. There is no transfer, however, of technology or license to Japan.

Mr. Lewis. I see. Just the equipment. OK.

Mr. Fri, on page 2 of your testimony you state that entering the marketplace with a continuation of prototypes and semiproduction units will involve private sector risk-sharing by the utility industry and the manufacturer. What is the magnitude of the financial risks that the utility industry faces?

Mr. **Fri**. Similar to the question you directed to Mr. Podolny, the total cost to the utility industry of purchasing those first 23 units under Mr. Podolny's program, I would guess is in the neighborhood of $400 million. Some percentage of that—and those will be at a premium price, that is, premium over what the subsequent units after the first 23 would be sold for at a competitive price—Mr. Podolny is probably in better shape than I am to estimate how much premium there is in there, but I would guess fully 25 or 30 percent is there, so that's the nature of the financial burden that the utility industry is taking on.

Once those prototypes operate, they are committed to that burden contractually but, as I said earlier, this has been reviewed in some detail by our board of directors and we believe it's a realistic and appropriate burden for the utility industry to take up.

Mr. **Lewis**. How will the industry be able to finance the higher costs of the first fuel cell units?

Mr. **Fri**. Well, there are a couple of ways. One is passing the hat to get additional support from individual utilities, because what we have here is a program that will benefit the entire industry, and the early utilities, particularly the prototype buyers, ought not to be expected to bear the full cost of a program that will benefit the entire industry. I think there will be some of that. Some of the hat will be passed through the Electric Power Research Institute, which is in a sense in that business of collecting money from many utilities and applying it in a targeted way, and their commitment has already been made.

The other thing that will happen is, I think we will find for these very first units a number of applications where the value of the unit exceeds what one would think of as a competitive price in the mature market, a situation where severe environmental constraints, severe siting constraints, a severe time constraint may make this unit attractive to individual utilities at a price above the price that they would normally pay, and I have a hunch that a number of those situations will show up in these early units.

Mr. **Lewis**. Would you like to further comment on it, Mr. Podolny?

Mr. **Podolny**. No; I think that's a fair representation of the financing. There is a perspective here which is a little difficult sometimes. The limited production lot which sets the stage—and you have to think of this, unfortunately, as a supreme market test of a new form of generator in the hands of the electric utility industry, and that's really the risk to the manufacturer—but in total we're talking about something like 250 megawatts. That 250 megawatts, assuming go ahead this year, will be delivered before 1990, which in round numbers would give us 6 years, let's say.

In the period of time of 6 years the utility industry, without any growth rate and without any requirement really except to sort of get out of its own way would have to buy roughly 72,000 megawatts, either refurbishment, replacement, or new capacity in areas where that is required. So the 250 megawatts which would be installed by 1990 by, say, 23 utilities if they were all individual and represent, say, 40 percent of the utility structure, is really very,

very small in terms of the investment for that particular type of generator as against the massive capacity they're going to buy in the first place. So if we look at the utility industry in the gross sense, it's not really an exhorbitant risk we're taking. The problem is, we have to identify singular companies, and I think that's the perspective we're working on.

Mr. LEWIS. Thank you.

Mr. Fri, has the fuel cell users group made any commitments with regard to the purchase of fuel cell powerplants?

Mr. FRI. No. The fuel cell users group will never purchase a powerplant. The whole object of the game is for individual utility companies to buy powerplants from individual manufacturers. Our role is to help educate the industry in how to do that, to help do what you might call missionary selling to get their own planning to the point where they want to buy one, but I think it's crucial in any commercialization effort that some kind of association such as ours does not stand in the way of the essential buyer-seller relationship which must take place between the individual seller and the individual buyer.

Mr. LEWIS. Thank you, Mr. Fri.

Dr. Baker, working within the Department of Energy—oh, I'm sorry. I want to ask you one more question, Mr. Fri.

Your users group suggests a 5-year commitment for fuel cell research and development with a minimum $40 million effort in fiscal 1985. What do you plan for subsequent years? Do you have any idea?

Mr. FRI. I would have to provide that information for the record in terms of specific dollars. Our objective, as I believe it says in my prepared remarks and as I tried to say in my testimony, is that continued development that leads to better economics, better performance. Higher chances of success of these first units on which the industry is going to spend a lot of money is very important to us, and I think highly leveraged money for the Federal Government, and that is the objective we are trying to achieve but I will have to give you specifics in writing, if I may.

Mr. LEWIS. Thank you.

Dr. Baker, working within the Department of Energy's request for the 1985 fuel cell program, how would you redirect money to increase the molten carbonate fuel cell budget by $1.3 million?

Dr. BAKER. Well, we are recommending an increase over the 1984 congressional appropriation of $9.2 million, so we're recommending an increase to $10.5 million, and we're suggesting that $3 million of those fund be spent at ERC in the development of the direct fuel cell. To this we would add funds from EPRI and our own funds to develop this project.

Mr. LEWIS. OK. Would you also please explain how your direct fuel cell differs from other molten carbonate technology and what its advantages are?

Dr. BAKER. Well, basically our direct fuel cell does not require an external fuel processor. We can convert fossil fuels, such as natural gas and methanol, directly in the fuel cell. This allows us to achieve extremely high efficiency, essentially 15 percent higher than other molten carbonate fuel cells and about 40 percent higher than the phosphoric acid fuel cell. This makes this the most efficient electric energy generator that's known. In addition, our particular system operates at atmospheric pressure and at somewhat lower temperatures and, therefore, the technology is somewhat easier to develop.

Mr. **Lewis**. Are there any others developing direct fuel cell concepts?

Dr. **Baker**. To the best of my knowledge there are several approaches to the direct fuel cell which involve different approaches to internal reforming. I think our company has pioneered the development of the direct fuel cell and has demonstrated the longest operating cells and the highest efficiency cells than any of the other approaches.

Mr. **Lewis**. Do you feel that you have a proprietary position in this technology?

Dr. **Baker**. We have a position, I think, that is significant. We have filed some patents and some patents have been issued to us in this area by the U.S. Patent Office, so I think that we would have a proprietary position here.

Mr. **Lewis**. Mr. Kalhammer, how long do you believe that continued support of the phosphoric acid fuel cell activity is justified, and at what funding level?

Mr. **Kalhammer**. We are talking——

Mr. **Lewis**. You may have made reference to this in your remarks, but I would like for you to——

Mr. **Kalhammer**. I have, but I am glad to respond to your question.

I think we must recognize that we are embarked on bringing to commercialization an entirely new technology that has never before been used on a commercial scale, much less by electric utilities. There are a number of very good reasons why the manufacturer and the funders like DOE and EPRI are pressing for this commercialization to take place rapidly so that the development resources remain limited, but we are also taking certain risks here that the technology will still require improvement.

So we are convinced that as long as you have a program of commercial prototypes and early commercial units, there is a continuing need for improvement of the technology, resolution of problems that will only become apparent in early uses, further improvement of certain critical features that will either make the powerplant more reliable, possibly more efficient, certainly lower in cost to produce.

I have not yet answered your question directly but I would say there is at the very least, in my view, a 5-year period during which R&D in the phosphoric acid fuel cell technology is going to be essential to facilitate the transition to the commercial arena.

Mr. **Lewis**. To what extent would you expect EPRI to participate?

Mr. **Kalhammer**. I believe I mentioned before that our entire budget for fuel cells over the next 5-year period is going to be approximately $75 million. About 80 percent of that is in fact going to the phosphoric acid fuel cell.

Mr. **Lewis**. I see. Does EPRI have any plans to support the first few demonstrations of large commercial prototype fuel cell powerplants?

Mr. KALHAMMER. Yes, indeed, we have. It's part of our 5-year plan, and a good part of the money that I just mentioned will go to supporting the early commercial prototypes.

Mr. LEWIS. Among the three processes presently being studied—the phosphoric acid, molten carbonate, and solid oxide—how would you apportion DOE funds? I believe you said EPRI funds would be about 80 percent for phosphoric, right?

Mr. KALHAMMER. That's correct.

Mr. LEWIS. How would you apportion the DOE funds for the other three?

Mr. KALHAMMER. I think it's appropriate for the Federal Government to have a somewhat different ratio, recognizing that the Federal orientation is more towards development and taking greater risks than the EPRI program, which is more of a near-term program. It would be our view that under the assumption that the Federal budget for fuel cells total for 1985, if that were again $42 or $43 million as last year, that perhaps about $27 million or so should go to the perfection of the phosphoric acid technology, perhaps $5 million might go to the on-site fuel cells, and the remainder should be spent on the advanced fuel cell technologies, divided between molten carbonate and the solid oxide.

Permit me one more remark. We do believe that the former amount, the $27 million or so that I think would be appropriate to support the phosphoric acid fuel cell development efforts, should contain I would say between $1 and $2 million also in fiscal 1985 to support the efforts at the 4.8 megawatt demonstrator in New York. That would mean basically a matching by DOE of the amount that EPRI is spending there.

Mr. LEWIS. I see.

Mr. Podolny, I would like to ask you a question about the New York City plant. I believe you are looking at a 3-year program to refurbish that New York City plant. Is that correct?

Mr. PODOLNY. I think our estimates are, you can refurbish the plant in five quarters.

Mr. LEWIS. I'm sorry. I missed that.

Mr. PODOLNY. But we recommend a program in which the powerplant would remain operational for about 3 or 4 years.

Mr. LEWIS. I see. Now there is a problem with the stack at the New York plant?

Mr. PODOLNY. At the present time there was a problem with 1 of 20 stacks which occurred just after Christmas in 1983. That stack has been removed and a spare stack which was tested and confirmed was installed, and the powerplant is now going through preoperational checkout.

Mr. LEWIS. Was that a technological problem with the stack, or——

Mr. PODOLNY. We don't know yet. We are in the process of disassembling the stack but our best understanding is, it's a mechanical failure not associated with fuel cell related technology per se, but we don't have the answer yet.

Mr. LEWIS. Thank you.

I would like to thank you gentlemen for coming and giving your testimony, particularly for keeping it brief. The record of this hearing will be held open to allow for inclusion of answers to written questions that you may receive from the various members of the committee, that they may have for you.

The subcommittee is adjourned, subject to the call of the Chair. Thank you.

[Whereupon, at 12:15 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

[Additional material submitted for the record follows:]

BARTLESVILLE AREA CHAMBER OF COMMERCE
COMMITTEE ON ENHANCED OIL RECOVERY RESEARCH
Bartlesville, Oklahoma 74005

RECEIVED
MAR 29 1984
COMMITTEE ON SCIENCE
AND TECHNOLOGY

March 23, 1984

Chairman Don Fuqua
Subcommittee on Energy Development
and Applications
Committee on Science and Technology
U.S. House of Representatives
Room B-374, Rayburn House Office Bldg.
Washington, D.C. 20515

Dear Mr. Chairman:

On March 7, 1984, your subcommittee held a hearing on the research and development budget for fossil fuels for the Department of Energy. Enclosed is a statement on petroleum research in enhanced oil recovery and the prospects for EOR to fill an important gap in our energy security. I ask that it be included as part of the hearing record.

This statement and the attachments make a strong case for increased R&D funding for enhanced oil recovery, both from a purely local supply perspective as well as the national security perspective. Much work remains for the federal sector if the benefits described are to be obtained by the country.

Thank you for your attention to this matter.

Sincerely,

Ralph L. Smith
Vice President, BACC
Chairman, BACC Committee on
EOR Research

Attachment

### STATEMENT OF RALPH L. SMITH
CHAIRMAN, COMMITTEE ON ENHANCED OIL RECOVERY
VICE PRESIDENT, BARTLESVILLE AREA CHAMBER OF COMMERCE
Bartlesville, Oklahoma 74005

A major national problem, becoming acute in certain states, is not being addressed. The problem is steadily declining domestic crude oil production with its attendant loss of local economic activity.

Despite a four-fold increase in real prices of crude oil in the past decade and a doubling of exploratory drilling, oil production in the continguous states has declined 25%. The simple truth is that, without a significant change in these trends, the domestic petroleum extraction industry is dying, different only in time from steel, consumer electronics, and automobiles in increased reliance on imports.

Oil producing states, recently flush with economic vitality, will follow Appalachia and the heavy industrial heartland into economic stagnation, unemployment, high social service costs, and decreasing tax bases (severence and income) to deal with these problems.

The only truly critical energy problem in the U.S. today is that we cannot produce enough liquid transportation fuels to meet our economy's demands. Unless something significant is done -- and soon -- the gap between demand and domestic supply can only widen -- increasing the reliance on imports that lies at the heart of the nation's energy, economic, diplomatic, balance of payments and military problems.

The reality of this problem is underscored by the recent spate of proposed and actual oil company mergers. The major operators know that it is substantially cheaper to buy someone else's reserves than to find new reserves of their own. While this may benefit the companies' stockholders and a number of corporate lawyers and investment bankers, it adds no new reserves, decreases competition, increases already difficult pressures on credit markets and interest rates (and, hence, probably inflation), and decreases state and Federal income tax revenues. (See the attached column by Hobart Rowan.)

The problem is becoming particularly acute in the major producing states. All, except California (assisted by thermal enhanced recovery of heavy oils) and Alaska (blessed with the largest field in the Western Hemisphere, which is itself about to begin to decline), have suffered significant decreases in production in the decade 1972-1982 (the latest years for which data are available), for example:

- Texas by 29%
- Louisiana by 45%
- Oklahoma by 24%
- New Mexico by 36%
- Wyoming by 16%
- Illinois by 21%
- Mississippi by 55%
- Utah by 16%

Essentially all producing states, including California and Alaska, have experienced declines in reserves. For ten producing states -- Oklahoma, Kansas, and nearly all states east of the Mississippi -- more than half of 1982 production was from marginal, "stripper" wells, averaging only 2.9 barrels per day, obviously approaching abandonment. In response to price increases, domestic exploration has doubled, but the average size of newly found fields has fallen dramatically. In aggregate, we are replacing with new reserves only about 22% of what we are producing.

Unlike the major, multi-national oil companies, the producing states can neither "merge" into new reserves nor "move on" to more promising exploration targets abroad. Nationally, the problem is yet one more declining domestic industry; at the state level it threatens severe economic disruptions.

This dire prediction belies the fact that more than 300 billion barrels of crude oil will be abandoned in known U.S. reservoirs at the conclusion of conventional primary and secondary recovery. This is twice as much as has been and will be conventionally produced from these reservoirs. The remaining oil, unlike that produced by conventional means, exists in a very different state, trapped in the reservoir rock by a variety of mechanisms. In fact, the residual oil is so different that, to receive the consideration it deserves, it should be considered in the same category as synthetic fuels -- although it is substantially lower cost to produce.

Producing a portion of this "residual oil" is the objective of enhanced oil recovery (EOR), a number of sophisticated, high-risk production technologies. EOR is the only approach that can offer the "significant change" described above -- the only way to offset or defer the inevitable, precipitous decline in domestic crude oil production and to sustain vulnerable state economies.

Three major engineering-economic studies in the latter 1970s predicted that EOR could substantially offset or stop the decline in domestic production at prevailing crude oil prices -- provided that sufficient R&D is done to make these complex processes predictable and effective enough to permit operators to use them. None of these projections has been proven by time. Enhanced oil recovery has not responded to the significant economic incentives that have been provided. The reason for this lack of response is the absence of fundamental understanding of the residual oil resource and the mechanisms for recovering it. The reason that the three earlier studies' projections have proven wrong is that the necessary research to produce this fundamental understanding has not been done.

Federal EOR research is designed to complement industry's R&D to generate a more complete understanding of this massive resource and the technologies to produce it.

Certain analysts, nearly all in Federal bureaucracies, have argued that EOR is currently commercial because some EOR is being produced. They have overlooked the fact that only ten U.S. counties with particularly favorable reservoirs account for essentially all EOR; Kern County, California alone accounts for 61% of the U.S. total. The reservoirs of these counties are not typical of the full residual oil resource base. But, based on the misunderstanding by these analysts and the absence of testimony to the contrary, adequate, stable funding has not been provided for Federal EOR research.

Given this lack of understanding by our law-makers, the absence of an organized oil-state coalition, a concerted effort by the utility industry through rate-supported consortia, and a variety of other institutional and political reasons, the nation's focus in energy research has been and continues to be on sources other than oil, e.g., coal, nuclear, synthetics. While each of these energy sources are important, they will not make a significant, cost-effective contribution to the transportation sector in this century. In fact, with the hundreds of millions of dollars spent on coal research, one might question what additional benefits the nation will receive. Ever more sophisticated processes for producing electricity have not brought rates down. Displacing of liquid fuels is unlikely; petroleum burned by utilities -- today mostly coke -- accounts for only 7% of utility fuels. None of this utility research does anything to offset the economic problems facing the major oil producing states. Through their consortia, and friends in Congress, gas and electric utilities are lobbying hard for increased Federal research. At the present time, eastern coal states and the electric power industry are proposing a five-year, guaranteed doubling of commitment to coal research; and gas interests are arguing to double funding for unconventional gas research.

By contrast, EOR directly addresses the central energy problem by increasing domestic production from known reservoirs and holds the potential for restoring production to the domestic oil industry and the oil-producing states. Unlike the utilities, however, there is no petroleum consortium or public coalition to carry the message.

Further, no witness before this subcommittee has stressed the need for R&D in EOR, while all of the other energy sources are extensively represented. This anomaly is similar to the absence of testimony on EOR last year and in most previous years from the industry, the affected states, or the research community. This does not mean that there is no recognition of the problem. The larger oil companies have invested heavily in EOR. However, as with mergers, their production decisions are based on existing oil economics, not long-term public needs. Most of these companies are involved in offshore and foreign exploration and with other, more predictable technologies to increase their reserves. The issues involved in EOR are apparently too complex for the smaller producers or individual states to address effectively. The results over the last two years were devastating reductions in EOR funding based on the incomplete understanding of the problem. This was done while essentially all other fossil energy research budgets were increased relative to Administration requests. The simple reason was lack of vocal support, generally based on lack of understanding of the problem and the potential.

The Administration has proposed an EOR research budget for $12.2 million for Fiscal Year 1985 (plus an additional $1.2 million for tar sands). While this is an increase over 1983 and 1984, it is much lower than prior budgets, it does not fully meet the most urgent R&D requirements. The proposed level permits only minimal research efforts by universities and National Laboratories, and no substantial cooperative arrangements with industry or the states. It does, however, meet the obligation to the defederalized cooperative agreement partner, the National Institute for Petroleum and Energy Research.

In our view, the Administration's request is too low by at least $5 million, even given current deficits. Adding these funds would permit full funding of the vital university and National Lab programs and permit more active cooperation with industry and the individual states. Our larger concern, however, is that history will be repeated: that in the absence of testimony or Administration emphasis, this subcommittee may decide to cut this program even below the Administration's modest request. This cannot be permitted to happen.

If, given the problem of the deficits, fossil energy research budget reductions are necessary, they should not be in the area where the national and state problems are most acute, petroleum, but where the problems are substantially less pressing. Our most critical problem is not how to burn coal or gas in utility boilers; it is how to sustain a vital domestic industry, support important state economies, and reduce reliance on imports.

In some states, the decline in oil production has already began to cause serious economic problems. Oklahoma is a good example. Oklahoma's recent decline has been somewhat less than some of the other large producing states only because it began earlier and has benefitted from prices and incentives to sustain production from marginal wells. In 1982, 64% of Oklahoma's production was from such "stripper" wells, with an average production of only 3.5 barrels per day -- clearly approaching abandonment. This decline (and the softening of oil prices) has caused the state to pass special "temporary" taxes and to reduce public services significantly. As taxes rise and services deteriorate, it will be increasingly difficult to attract the new industry needed to replace the rapidly declining Oklahoma oil industry. As Oklahoma's wells are abandoned, however, nearly two-thirds of its known oil -- 26 billion barrels -- will remain in the reservoir. The only opportunity to sustain oil-related Oklahoma activity and to produce a portion of this oil is EOR. If enhanced recovery can be applied, the state may have "breathing room" of ten to twenty years in which to develop or attract new industry. Without EOR, economic stagnation is essentially inevitable. Oklahoma is not unique in this. All major producing states are or will soon be confronted with the same situation.

This is a public, not private, issue. Multi-national companies have alternative, often foreign sources of crude oil. EOR technology is currently too risky for smaller operators; they will simply leave the industry. Well-funded lobbies continue to direct Federal R&D toward other fuels. The real "losers" from those trends are the citizens of the producing states, faced with higher taxes, reduced services, and decreased economic opportunity. The only public option available is Federal EOR research and development. It should be funded at adequate levels and directed to work cooperatively with the states and the industry to assure the EOR opportunity is realized.

Attached are two briefings prepared by the DOE that detail the situation facing the declining domestic petroleum industry and how EOR -- and Federal EOR research -- can help.

As we have considered the issue of EOR research, a related idea repeatly comes up, but apparently finds no institutional "home" in the Federal establishment either congressional or administrative. The idea is that EOR can play a vital role in the nation's energy preparedness, under certain specific conditions.

We observe the Federal government spending billions of dollars on the Strategic Petroleum Reserve (SPR) to cope with import disruptions of intense proportions but relatively short duration; we see allocations of additional billions of dollars for synthetic fuels to cope with disruptions of very long duration or permanent termination of imports. A gap exists in our preparedness strategy for disruptions of an intermediate duration (e.g., 1-3 + years). As demonstrated in the attached White Paper, it appears that EOR, with appropriate planning and "pre-engineering," could fill this gap. Thus, the need for Congressional direction.

Note: EOR is neither an alternative nor a competitor of SPR or synfuels; it represents the complement of a continuum that is now incomplete. The concept has not been further developed because EOR lies outside the mandate of DOE's emergency preparedness staff and emergency responses lie outside of the mission of DOE's experts in EOR.

The White Paper contains a detailed definition of the concept of "pre-engineering" and a qualitative analysis of the prospect for EOR to meet emergency requirements of 385 thousand barrels per day within one year and about one million barrels per day within two years. The analysis suggests that a relatively small number of highly important reservoirs could meet these requirements. If the "pre-engineering" needed to achieve this level of readiness were developed cooperatively with industry, this could be a highly cost-effective complement to the nation's energy preparedness strategy while accelerating EOR applications in the absence of an emergency, thereby reducing overall vulnerability.

The analyses done to date, however, are only suggestive. The White Paper has been favorably reviewed by experts in industry and government. The comments to date argue that the concept has merit but also point up the need for more detailed engineering/economic analyses of the feasibility of the concept and an evaluation of alternative means for implementing it. A voluntary, industry-government cooperative approach could well yield substantial benefits to both the nation and the participating companies while working through basic market mechanisms.

Fortunately, the National Petroleum Council (NPC -- an industry advisory committee to the Secretary of Energy) is currently completing an in-depth analysis of the potential of EOR under non-emergency conditions. Due to the intensive cooperation of the DOE Bartlesville Project Office (BPO -- the Federal successor to the defederalized Bartlesville Energy Technology Center, who developed the White Paper), the reservoir data base and EOR process and economic models used by the NPC now reside on the BPO computer. This highly credible basis of data and models could be used to perform the needed preliminary feasibility and benefit-cost analyses. The first order questions are highly technical, relying on geological, technological, and economic assessments of whether EOR can actually meet specific targets for emergency production. The second set of questions pertain to how best to implement the appropriate program in collaboration with industry, and the benefits and costs of various alternatives; these call for both policy and technical/economic analyses. Once these issues have been successfully addressed, the third-order questions of needed legislation (if any) and appropriate programmatic guidance come to bear.

With the reorganization of the Department of Energy, consolidating the management of SPR with the Fossil Energy R&D function (which includes EOR), we believe that the time is appropriate to examine the detailed feasibility of EOR as a complement to the present emergency preparedness strategy.

Toward this end, we ask that you introduce into the authorization process a directive that the Secretary of Energy conduct a detailed feasibility study of the potential benefits and costs for EOR to contribute to an overall energy preparedness strategy. The funding for the in-depth study should be an additional one million dollars. The directive should explicitly request that the Secretary employ the reservoir data and models used by the NPC (or contemporary, updated versions of these) to conduct the study. The direction should include a report to the Congress within eighteen months of the appropriation. The report should include a detailed technical assessment of the feasibility of EOR in emergency preparedness, alternatives for implementing this concept (if technically feasible), an assessment of the benefits and costs of each alternative, and a recommended plan of implementation.

While we ask that you introduce this concept, we hope you will also seek to assure its inclusion in the appropriating legislation. We very strongly believe that EOR as a complement to the nation's energy security posture, is an idea that has been overlooked. It is time to correct this oversight.

What is needed now is far-sighted leadership of those who understand the problem, especially in the Congress. EOR research, with a coordinated use of EOR as an energy security fuel, will have significant, highly cost-effective benefits to the nation and to the producing states. Our Committee hopes you will see the urgency of this issue as we do and provide support of an adequate Federal EOR research and emergency preparedness program.

Thank you for joining us in this important national effort.

DON FUQUA (Fla.), Chairman

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Minority Staff Director

April 2, 1984

Dr. Richard D. Wolfe
Vice President, Research & Development
United Coal Company
Bristol, Virginia 24101

Dear Dr. Wolfe:

Thank you for your testimony before the Subcommittee on Energy Develoment and Applications on March 7, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 20. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

DON FUQUA
Chairman

DF:Kcw
attachment

*United Coal Company*
*P. O. Box 1280, Glenway Avenue*
*Bristol, Virginia 24203*

*Tel. (703) 466-3322*
*TWX: 510-580-2108*

April 18, 1984

The Honorable Don Fuqua, Chairman
U.S. House of Representative
Committee on Science and Technology
Suite 2321 Rayburn House Office Bldg.
Washington, DC 20515

Dear Mr. Fuqua:

As a representative of United Coal Company and, therefore, the coal industry, I certainly appreciate the opportunity to testify on March 7, 1984. I sincerely believe that the increase in the coal budget, which was supported by your committee, was a tremendous contribution to funding research and development so desparately needed to develop new markets for coal.

The questions you ask in your April 2, letter addressed in the separate attachment, I am more than pleased to respond, as follows:

1. Please explain what technological breakthroughs might be expected in coal R&D, as you allude to in your testimony?

With regard to technical breakthroughs, the major emphasis of my testimony was directed toward developing new liquid forms of coal. For example; diesel, marine and naval applications for replacing diesel fuel with a coal based liquid fuel; secondly, developing a liquid coal based fuel to replace diesel fuel being used in locomotive engines, and third, developing new liquid based fuel to replace oil being used in stationary diesel electrical powered facilities and gas turbines. By identifying these prime areas for coal utilization, then we should structure our R&D program to directly develop a coal liquid based fuel. Research work that we are doing here at UCC, as well as, other research organizations sponsored by the DOE indicated that with further research, we can directly and economically develop a new liquid based coal fuel that can replace diesel fuel in the markets I have mentioned.

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2. DOE is looking at several coal cleaning technologies right now. What additional technologies do you suggest be investigated with the almost $13 million you suggest adding to this program?

With regard to coal cleaning technologies, certainly the area of further research and technology development needs to focus on providing and developing new technologies to ultra/clean coal of its impurities to levels that are competitive with oil. In this regard, we must develop technologies that can clean coal of its ash and sulfur to levels less than 1%. Several new areas, such as microbiology similar to what has been used in sewer treatment, is possible to develop microrganisms that will remove sulfur from coal to levels than ever achieved. Additional research needs to be supported in this area. Also, various new chemical leaching methods are being explored by UCC and others that show that both ash and sulfur can be lowered to these levels. Again, this ultra/cleaning is high risk research and certainly is of the proper nature to be funded by the Federal Government. The third area of coal cleaning involves the methods of dewatering the ultra/fine coal that is necessary in liberating ash and sulfur. The area of drying this ultra/fine coal could have a tremendous benefit in further recovering coal from the waste, as well as, obtaining a more premium product that is of higher heat quantities than currently available. So in summary, the three major new areas in coal cleaning are: (1) Microbiological cleaning; (2) acid leaching and chemical cleaning, and (3) advanced technology to dewatering fine particle waste coal.

3. In your opinion, what is the proper role for the Federal Government to pursue in developing the fossil resources of this country?

The Federal Government, and particularly the DOE, has a responsibility to the taxpayers of this country to further the technical development to obtain energy independence. In this regard, we should set forth specific technology development dollars to achieve that goal. I certainly believe the Federal Government should spend those dollars wisely and provide the catalyst on higher risk research necessary to develop new uses of coal. I have been greatly concerned with the current administration's emphasis on increased research for nuclear energy development, which takes away much of the funding that could go to the Fossil Energy Program. Greater energy development and energy independence can be achieved by funding coal technology development than any other research area. The proper role for the Federal Government appears to me to be in the area of evaluating the feasibility of new technology with direct relationship to developing new markets for increased coal utilizations. The coal industry is not nearly as advanced as the aerospace, nuclear or chemical industry, which has, over the past two decades, received the majority of the Government's advancement technology development funds. As a result, I believe it is necessary that the coal research go beyond just the technical feasibility, but to the additional stage of bench scale pilot plant type verification. I definitely believe also that large scale demonstration projects may not be the best use of the Federal Dollars, unless the industry is brought into contributing significantly to these demonstration type projects. However, I believe the Federal Government can provide the "catalyst" type of initial funding to explore the technical and economical feasibility and encourage the coal industry specifically to become an integeral part of the technical development.

Mr. Fuqua, while I was with the Federal Government for five years, 1974-1979, with ERDA and DOE, I tried to influence the industry that will ultimately utilize the technology. These direct involvements of industries should be an integeral part of the development of the technology. Far too much of the Government R&D funds goes to those "Beltway Bandit Organizations" that live and die off the Federal dollar. Much of the coal technology development funds in the past has gone to such organizations. Whereas, little, if any of that technology is ever transferred to the coal industry. That is one of the prime motiviations for UCC to establish a research organization so that we can be involved and set the pattern for other coal companies to follow in working with the Federal Government. I definitely believe that the DOE can structure some of its coal technology funds specifically for development by coal companies. This could be a requirement to encourage other coal companies to participate competively for the funding, rather than the high technology firms who normally seek these type of contracts. In so doing, I believe we can directly improve coal research being constructed throughout the coal industry.

4. Working within the program funding request, how would you rearrange funds to meet your priorities?

With regard to rearranging the DOE funds, I certainly believe the basis of the coal research program should be first and foremost oriented toward new liquid developments that will further utilize coal as a direct replacement for oil. In this regard, I would structure the programs to emphasize new liquid forms of coal, advanced coal cleaning, resource recovery from coal waste, burning of liquid coal or ultra/clean dry pulverized coal in diesel engines, gasoline engines, turbines and other types of heat engines. This market alone, if if could be developed would require as much as 75 to 100 million tons of additional coal use per year. At the same time, it would directly reduce imported oil and provide additional energy independence. In addition, I believe we must continue advance development of liquification and gasification, which has relations to the development of the new synfuels industry. I believe that additional tax incentives and other types of Government incentives could be provided without federal R&D dollars to encourage more coal conversions such as those related to the synfuel development. In this regard, certainly a Government sponsored program directly in the coal industry could further justify coal conversion technology such as those now being commercialized in converting coal to methanol plants. Tennessee Eastman has already built the first U.S. commercial synfuels plant. However, much of the basic gasification and liquification technology was sponsored by the Federal coal program during the past decade and it is one of the best examples that can be referred to of where the Federal Government has helped develop the basic technology. This vital role in developing the basic technology that has stimulated the commercial applications of this new industry.

I would restructure the program so that the last emphasis would be upon the direct combustion of coal to make electricity. The environmental control technology is extremely important to be able to burn coal more cleaner in meeting certain reasonable environmental regulations and that emphasis should be conducted. However, such advanced technology as fluidized bed, MHD, and new combustion boiler designs I feel should take a lower priority, although important, than that technology that will development new outlets for coal.

I appreciate the opportunity to respond to your questions. I apologize for the length of these answers. However, your questions are so important the further understanding the needs of the coal industry from a technical advancement standpoint, that I wanted to answer them to the best of my knowledge.

If I can be of any continuing service to your committee to further support and justify coal research, please let me know. I would be honored and would be glad to do so.

Best regards,

Richard A. Wolfe

Richard A. Wolfe, Ph.D.
Executive Vice President
UCC Research Corporation

RAW/afg

cc: Congressman Rick Boucher

DON FUQUA (Fla.), Chairman

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April 2, 1984

Dr. George W. Roberts
Air Products and Chemicals, Inc.
1800 K Street, N.W., Suite 1016
Washington, D.C. 20006

Dear Dr. Roberts:

Thank you for your testimony before the Subcommittee on Energy Develoment and Applications on March 7, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 20. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Kcw
attachment

Air Products

Air Products and Chemicals, Inc.
Box 538, Allentown, PA 18105
(215) 481-4911

17 April 1984

The Honorable Don Fuqua
Chairman
Committee on Science and Technology
U.S. House of Representatives
Suite 2321, Rayburn House Office Building
Wasnington, DC 20515

Dear Mr. Fuqua:

Thank you for your letter of April 2, 1984. I appreciate the interest shown by the Members of the Subcommittee on Energy Development and Applications, and I am pleased to respond to your questions concerning my recent testimony. Attached you will find a copy of the questions together with my responses.

If you have any other questions or would like further information, please let me know.

Sincerely,

George W. Roberts/EJH
George W. Roberts

GWR:sde
attachment

cc: Mr. Robert Kripowicz,
Subcommittee Staff Director

**Questions for Dr. Roberts**

1. You call for the specific ear-marking of $5 million for the DOE Process Development Unit at LaPorte, Texas. These funds will permit, you indicate, further development of new cost-effective technology for producing methanol from coal.

a. What specific research do you propose to be undertaken? b. How much will the private sector fund?

c. Is it directly related to indirect liquefaction technology or generic research?

d. How much empirical data is needed to make the Air Products liquid phase methanol process a predictive process?

e. How long would you suggest the facility be operated?

f. What is the Electric Power Research Institute's interest in this work?

2. Can development of new catalysts or processes other than the existing work now underway be accomodated in the La Porte facility?

## Answers for the Subcommittee

1a The proposed research program would have three main areas of activity:

1) Defining the limits of reactor productivity.

This would include: a) studying the effect of catalyst loading on methanol production rate and defining the maximum catalyst loading beyond which operation is unsatisfactory; b) studying the effect of gas velocity on methanol production rate and defining the maximum gas velocity beyond which reactor productivity deteriorates or operation is unsatisfactory and; c) synthesizing and testing potentially more active catalysts to increase reactor productivity.

2) Developing a data base for design of the demonstration plant.

With the preferred catalyst, extensive runs would be made to quantitatively define the effect of variables such as space velocity, gas velocity, reactant concentrations, total pressure and reactor temperature on syngas conversion and methanol productivity. These data would be correlated and mathematical models of reactor operation would be developed. This set of data correlations and models would provide a strong technical base for the design of a demonstration plant in the 100 to 200 T/D range.

3) Conducting durability studies.

Long runs would be made to quantitatively determine the rate of deactivation of the preferred catalyst (catalyst life) and to determine the life of certain critical components such as the slurry pump, slurry letdown valves, etc.

1b The private sector would share the cost of the proposed research at the same percentage as in the present contract. We believe that the present level of cost-share (11.9% private funds) is appropriate in view of the fact that the proposed program contains a strong element of long-range, high-risk research.

1c The proposed program is related to both indirect liquefaction technology and to generic coal liquefaction research. The work being conducted on reactor designs and on catalyst performance provides broad support for other indirect liquefaction processes, such as liquid-phase Fischer-Tropsch and liquid-phase Mobile-M. Moreover, the fundamental studies of three-phase (gas, liquid, solid) flow that will be carried out will also serve to extend the knowledge base for direct liquefaction processes, which also frequently involve three-phase flow.

1d We currently project that two years (FY 1985 and 1986) of additional work in the LaPorte PDU will be necessary to develop the correlations, mathematical models and technical data base required to design a demonstration plant in the 100 to 200 T/D range. The performance of that demonstration plant will determine the adequacy of the above correlations, models and data base as predictive tools.

1e As noted above, the LaPorte PDU should be operated for an additional 2 years on the LPMeOH process. Further PDU-scale experimentation on LPMeOH should not be required beyond that time. However, it is possible that other indirect liquefaction technologies will be ready for testing at the PDU scale when the work on LPMeOH is complete. There is no need to make a firm decision concerning these newer technologies at this time.

1f The Electric Power Research Institute feels that the LPMeOH process can be used in conjunction with combined cycle coal gasification power plants to add flexibility to these plants and to provide economic improvements. Because of their strong interest in the LPMeOH process, EPRI is a part of the cost-sharing consortium on the present DOE contract and will continue as a cost-sharing partner in the proposed additional contract.

2 It is probable that new processes and new catalysts for indirect liquefaction can be developed in the LaPorte facility without any significant modification of the equipment. However, it would not be practical to attempt to time-share the facility between two processes in order to develop both simultaneously.

Long range thinking beyond LPMeOH at LaPorte should include technical data base development for other innovative indirect liquefaction technologies such as the new Liquid Phase Fischer-Tropsch process which is aimed at improved techniques for diesel fuel production. Work at LaPorte on such technologies could commence in approximately the FY 1987 time frame if existing bench scale work proves fruitful.

DON FUQUA (Fla.), Chairman

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Minority Staff Director

April 2, 1984

Kurt Yeager, Vice President
Coal Combustion Systems
Electric Power Research Institute
Palo Alto, California 94303

Dear Mr. Yeager:

Thank you for your testimony before the Subcommittee on Energy Develoment and Applications on March 7, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 20. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

DON FUQUA
Chairman

DF:Kcw
attachment

EPRI
Electric Power
Research Institute

April 20, 1984

Honorable Don Fuqua
Chairman
Committee on Science and Technology
U.S. House of Representatives
Suite 2321, Rayburn House Office Bldg.
Washington, DC 20515

Dear Mr. Fuqua:

The following is in response to your letter of April 2 conveying additional questions concerning my March 6, 1984 testimony to the Subcommittee on Energy Development and Applications.

Question 1: What is EPRI doing to work toward a joint effort with the Federal Government, and where is further cooperation or funding necessary?

Answer:

At the present time the resources available from either Federal or private sources are inadequate to confidently assure the development and commercialization of improved coal combustion technology. While private sector efforts have been maintained at a relatively constant level, Federal participation has declined substantially without corresponding incentives for additional private investment. This may have profound consequences for the 1990's when new electric generating demands, which must rely on coal, collide with the growing environmental ethic of our society. We know how to produce power cleanly from coal, the question is whether we can reduce this knowledge to commercial practice in a period when both regulatory uncertainty and financial disincentives constrain the effort? The problem affects all phases of the development cycle but is greatest in the financially intensive large pilot and demonstration steps necessary for commercial confidence.

EPRI joint efforts with the Federal Government in coal combustion are focusing on the following:

3412 Hillview Avenue, Post Office Box 10412, Palo Alto, CA 94303 Telephone (415) 855-2000
*Washington Office 1800 Massachusetts Ave., NW, Suite 700, Washington, DC 20036 (202) 872-9222*

a. Coal Cleaning. DOE and EPRI are implementing a joint project to test advanced physical coal cleaning processes. DOE will fund development testing of a series of such processes. EPRI will make available its Coal Cleaning Test Facility and will participate in the testing and evaluation effort as well as provide operating support services as discussed in response to question 2.

b. Flue Gas Cleaning. DOE and EPRI maintained a close working relationship, particularly in the field characterization and improvement of $SO_2$ scrubber reliability. Unfortunately, this effort was interrupted by the termination of DOE funding in 1981. We strongly encourage the proposed resumption of DOE participation, and in technology to eliminate the production of waste sludge from scrubbers.

   We have also proposed that DOE cofund and participate in our new High Sulfur Test Center being built to address the chemistry and materials issues limiting flue gas desulfurization (FGD) performance and reliability. DOE participation of $7 million could accelerate the availability of this facility from 1989 to 1986 and expand the capability. This could have a substantial impact on any acid rain control strategy requiring retrofittable FGD.

   A third area of flue gas cleaning in which we have encouraged increased DOE participation is particulate control technology improvement. As I point out on page 14 of my testimony, all the technologies to reduce $SO_2$ emissions, from coal cleaning to scrubbers, will have a detrimental effect on particulate control. Specific issues and joint development programs have been identified if additional funding of about $5 million per year can be provided.

c. Limestone Injection (LIMB). EPRI and EPA have maintained coordination during our complementary efforts in small-scale development of dry furnace limestone injection technology. We believe, however, that scale-up requirements and funding limitations encourage a single, joint field demonstration program. We are hopeful that recent actions by EPA signal a greater willingness to entertain such a joint effort (see question 3).

The primary limiting factor is funding. Less than half the $65 million jointly necessary to develop and demonstrate this technology over the next five years, is budgeted. We also believe that DOE can and should play an important role in the Federal effort on this technology, as they do in other $SO_2$ control developments, to avoid regulatory conflicts of interest and resulting impacts on user confidence.

d. PFBC. Initially, EPRI and DOE coordinated the planning and implementation of a national PFBC program. The effectiveness, however, has been constrained by the very limited and uncertain Federal budget. We recommend that the DOE effort in PFBC focus on the low temperature, turbocharged boiler being stressed by EPRI and the U.S. manufacturers rather than the longer range, combined cycle approach. This "coal-fired gas turbine" technology can reduce the time and cost of construction dramatically while making maximum use of existing plant sites - all important factors for the 1990's. It will, however, require a more concerted effort, of $10 million per year for the next 2 to 3 years at the Grimethorpe and the Curtiss-Wright pilot facilities, to make this technology a reality this decade.

e. Coal-Water Slurry (CWS). EPRI has encouraged DOE to stress the development of reliable, retrofittable burners rather than just a slurry properties data base. This, and the availability of an adequate CWS supply for demonstration purposes are the pacing items in reducing the CWS oil backout option to commercial readiness. Federal participation either in the capital cost or in product price guarantees will probably also be necessary if an adequate CWS supply is to be available this decade.

| Question 2: | What is the magnitude of the joint DOE/EPRI coal preparation program being developed at Homer City? |
|---|---|

Answer:

DOE is planning to spend $4 million over 2-3 years on this joint program. EPRI will make available the resources and capabilities of its' $15.2 million Coal Cleaning Test Facility (CCTF), will provide technical expertise, and testing support services. The cost to EPRI of this joint program is about $500,000 per year in additional equipment, manpower and services.

Question 3: Given the problems of retrofitting scrubber technology in existing power plants, what are the chances of success of DOE's new initiative in this area? What kinds of technology should be included in this program? Will EPRI be involved?

Answer:

We understand that DOE's new initiative in reducing the cost of acid rain retrofit will include funding of the Grand Forks Energy Center research in pressure hydrated dolomitic lime and other dry sorbent injection options. These are relatively high risk technologies, but they represent approaches that would radically reduce the capital cost of $SO_2$ removal equipment. If successful, we expect dry injection technology to cost 25-50% of conventional wet scrubbing depending on the specific needs of the utility site. DOE's investigation into low cost materials for use in dry injection is an important step to broaden the options for $SO_2$ removal. EPRI, DOE and EPA have all coordinated work in this area in the past.

We feel DOE could usefully broaden their investigation of cost reduction methods by also modifying wet scrubbing technologies. This R&D is lower risk and the potential retrofit cost savings are on the order of 20-40%. This savings would be achieved by developing space-saving configurations for existing FGD designs and by developing gypsum-producing FGD processes to avoid disposal area on retrofits. As indicated under question 1, EPRI is initiating a High Sulfur Test Center to address these needs, and has proposed DOE's participation. This is under consideration but no firm agreements have been reached yet.

We also encourage a renewal of the joint program on field characterization of operational $SO_2$ scrubbers. This was terminated when DOE funding was withdrawn in 1981. This program provides an accurate diagnosis of technical and operating issues in scrubbers to guide industry-wide corrective action as well as to define the most effective additional R&D. Three to four characterizations a year of different scrubber designs and operating conditions are recommended at a cost of about $1 million each.

Question 4: What is EPA's reaction to the EPRI concept for LIMB scale-up? What are the differences in approach and why do we feel ours is more appropriate?

Answer:

EPA originally rejected participation in the the EPRI prototype scale-up approach which involves initially testing a broader range of conditions at a smaller (30 to 100 MW) scale. EPA has cited prior demonstration commitments to Congress as a major consideration in bypassing this participation and has encouraged us to proceed independently. However, EPA has now issued their RFP for LIMB demonstration contractors and it does not specify boiler size. We conclude, therefore, that EPA may be finding the concept of smaller boiler size more acceptable. They have also indicated difficulty in locating a larger boiler which could be committed to such a test. We also believe that the cost of the LIMB demonstration program has been underestimated and may financially require a smaller boiler unless further funding is provided. We remain hopeful that a joint program encompassing the range of varibles affecting this technology can be promptly implemented at several sites using a consistent set of test criteria. We believe this is the key to validating the technology for commercial use but will require increased Federal and private funding.

The attached letter to Dr. Goldstein of EPA summarizes the EPRI approach and rationale for LIMB scale-up. The reasons why we believe this approach has a higher probability of success are also described on page 12 of my testimony.

Question 5: There have been many comments to the effect that the Environmental Protection Agency places sole responsibility for sulfur reduction on the consumer, in your case, the utility. If this is so, there is little motivation for the utility to pay a premium rate for low-sulfur coal. Please comment.

Answer:

The question gets to the heart of the difficulty in relying on the adversarial approach to environmental protection. The financial incentive to the affected sources is heavily on the side of legally contesting or delaying control action as long as possible. Alternatively, an approach which uses profitability incentives to encourage environmental goals would be more conducive to constructive action. This holds true for low-sulfur coal, scrubbers or new clean coal technology. In all cases, legislation and regulation should provide maximum flexibility to the affected sources to choose the most cost-effective means of achieving the desired control level. Administrative proscriptions on technical choice should be avoided.

Question 6: What studies has EPRI made to compare costs of various emission control processes to attain an acceptable emissions level in the direct combustion process? For example, is it more economically attractive to remove sulfur by physical cleaning, chemical cleaning, a process such as LIMB, or flue gas cleanup?

Answer:

EPRI has sponsored many studies over the last few years to identify costs for emission control. The costs for each control technology can vary greatly from site to site depending on coal type, sulfur content, unit design, space available for retrofit, future unit life, etc. For example, costs for physical coal cleaning and flue gas desulfurization (FGD) have recently been studied with the range for coal cleaning approximately \$300 to \$2800/ton of $SO_2$ removed. This tenfold range is primarily based on the wide range in coal sulfur content and cleanability experienced nationally. A typical range for high sulfur, North Appalachian or Illinois Basin coal is about \$400-\$800/ton of $SO_2$ removed. The cost for FGD is approximately \$1000-\$1400/ton of $SO_2$ removed. LIMB, if successfully developed, is estimated to cost about \$650-\$1000/ton $SO_2$ removed. I am attaching a comparison table of $SO_2$ and $NO_x$ control technologies which outlines these relationships in more detail. I would also refer to my testimony to your Committee at the September 20, 1983 Joint Hearing on Acid Rain - Implications for Fossil Energy R&D for a more in-depth discussion of the application and costs of these various emission control processes. From a user standpoint, the option which is least capital intensive and involves the least loss of operating performance will be preferred. These are site specific decisions but generally, flue gas scrubbing will be the least preferred approach economically. Unfortunately, the administrative judgements on best available control technology broadly require the use of scrubbers today. Emerging technology such as fluidized bed combustion and coal conversion can, however, also meet these control levels but potentially without the economic and operational drawbacks.

Question 7: With regard to gas stream clean-up for PFBC, where and when does EPRI plan to scale-up the technology?

Answer:

The scale-up testing of advanced gas stream clean-up options for PFBC could occur either at Grimethorpe, Curtiss-Wright or the Stal Laval PFBC pilot facilities. Unfortunately, the availability of any of these facilities and the cost to support such testing is uncertain. As a result, EPRI is unable to proceed past the preliminary design phase on the necessary gas clean-up test module and its interface with the quite different PFB combustor designs at these locations.

Based on the progress of the DOE and EPRI research and evaluation efforts on hot gas cleanup, we believe such a scale-up program could be technically initiated in 1985 and should be continued for three years. It could be incorporated with the broader PFBC pilot effort at Grimethorpe and Curtiss-Wright recommended in question 1.

As indicated on pages 23-24 of my March 6 testimony, EPRI and several utilities are planning commercial scale demonstrations if these pilot efforts verify the performance and reliability advantages of PFBC.

Question 8: How many tests will be necessary to characterize long-term tube bundle life, configurations, and placement?

Answer:

The problem of tube erosion in PFBC is particularly difficult to resolve since we do not yet fully understand its root cause. As a result, a definitive answer to this question cannot yet be given. Both B&W and Foster-Wheeler are actively engaged in research and design efforts to resolve this problem. Whether these efforts are successful will require substantial, long-term testing at Grimethorpe with the candidate tube bundle designs. Bed oscillations, for example, may play an important part and it may take several years of coordinated research and pilot testing to resolve this problem and develop the necessary design guidelines.

We, therefore, also recommend a major supporting effort on fundamental measurements and small-scale research to establish the root-cause of erosion and provide design and operating guidelines which can be confidently applied. EPRI is participating in one such project but a number are required if this problem is to be resolved promptly. In addition, we have encouraged Combustion Engineering, together with LURGI, to develop a circulating PFBC. This may eliminate the conditions leading to bed tube erosion. EPRI is conducting a comparative engineering analysis of this design and the conventional bubbling bed approach.

Question 9: Would EPRI be willing to assist in funding a study in conjunction with DOE to ascertain the usefulness of using the BIGAS facility at Homer City, Pennsylvania, as a site for advanced combustion testing center?

Answer:

We have already undertaken the following actions in this regard.

- We have contacted all the U.S. steam generator manufacturers, major coal suppliers, and a number of utilities to identify the industry needs. A large (150-200 M Btu/hr), multi-burner, combustion test facility is recommended to provide meaningful design and scale-up data for new combustion hardware and related, in-furnace emission control technology. Such a facility does not now exist in this country.

- In order to evaluate the potential of a site such as the DOE BIGAS facility, a more detailed definition of the industry needs and operational support capability should be developed. This should include design, size, and capability requirements of the combustion testing center; front-end requirements (coal handling and preparation); back-end requirements (gaseous and particulate emission control, ash handling system); and measurement/diagnostic system requirements. EPRI would be pleased to join with DOE and other interested parties in a study to promptly address these issues. The effort should be sufficient to:

    1. Support the evaluation of the BIGAS facility as a combustion test center site, and

    2. Develop a specification for the detailed design and construction of the desired combustion test facility.

Question 10: What is the extent of EPRI's proposed participation in the Curtiss-Wright pilot PFBC facility? Will boiler manufacturers be involved in the program?

Answer:

We are acting as technical advisors to Public Service Electric and Gas. If they are awarded a contract we would help them develop and implement a test program. EPRI participation during testing would involve technical and operational analysis support plus development of design and operating guidelines in technical transfer. If the facility operates successfully, we would hope to augment the hot-gas cleanup test phase with advanced technology resulting from both DOE and EPRI research.

We recommend that the Curtiss-Wright testing effort involve all sectors of industry in hands-on roles, including the boiler manufacturers, just as has been done at the TVA 20 MW AFBC pilot plant near Paducah, Kentucky. We believe the Curtiss-Wright facility's unique ability to help resolve questions of PFBC system reliability and control will require the active participation of the boiler and gas turbine manufacturers. These requirements should take priority in any test plan for the facility.

I appreciate this, and my previous opportunities, to offer information to your Committee. I look forward to hearing from you or your staff at any time I can be of assistance.

Sincerely yours,

Kurt Yeager

Kurt E. Yeager
Vice President
Coal Combustion Systems Division

KEY:vbe

Attachments

cc: R. Kripowicz

EPRI
Electric Power
Research Institute

February 24, 1984

Dr. Bernard Goldstein
Assistant Administrator for R&D
U.S. Environmental Protection Agency
401 "M" Street, S.W.
Washington, DC 20460

Dear Dr. Goldstein:

The concept of direct furnace injection of limestone in combination with low-$NO_x$ burners has emerged as a potentially lower-cost approach for simultaneously controlling $SO_2$ and $NO_x$ emissions from existing coal-fired power plants. EPRI is pursuing a major research and development program aimed at determining the commercial viability of this process for the utility industry. In many respects, our research approach to date is similar to that of EPA's LIMB program; however, the strategies for scale-up of the technology are significantly different. The purpose of this letter is to acquaint you with the rationale and details of the EPRI program, compare respective development strategies, and solicit your ideas concerning coordination of future efforts to the mutual benefit of our organizations and the nation.

The joint focus of current R&D efforts is the development of process design and operating criteria for optimum $SO_2$ and $NO_x$ removal over the range of existing boiler designs and coal conditions. Similar to the EPA program, our work includes bench and pilot-scale testing and engineering design studies. A main portion of EPRI work is now being performed in a jointly funded project with the Southern Company Services organization. Additional efforts are also planned or underway to identify and resolve potential downstream plant system impacts such as effects on furnace ash deposits, ash handling and electrostatic precipitator performance. If successful, the limestone injection process could lead to reduced capital costs when compared to conventional wet $SO_2$ scrubbing options.

These laboratory projects are laying the groundwork for prototype tests of the limestone injection process at a number of small utility boilers in the 40-100 MW size range. We believe that the prototype tests are an integral part of the development process to provide the confidence for demonstration and ultimate commercial application. The issue here is the impact on

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the performance and reliability of the boiler and particulate control system, not just $SO_2$ removal efficiency. This approach is substantially different than the commercialization path that EPA is now pursuing, which involves as a next step a demonstration of LIMB technology at a single 250 MW (or larger)utility boiler. We believe our approach has a much higher potential for both promptly determining the operational potential of this technology and providing confidence for commercial application.

Our pursuit of prototype testing at several coal-fired utility boilers in the 40 to 100 MW size range is motivated by a variety of factors:

(1) The prototypes will enable final optimization of process design and the resolution of retrofit and performance issues that cannot be fully accomplished in the laboratory. The cost of performing this experimental work at a full-scale boiler would be prohibitive. Furthermore, we feel that the design and operation of limestone injection systems with the flexibility necessary to perform this work would be more practical at smaller boilers. These boilers would also be more likely to accommodate the load demands and frequent outages required in any case.

(2) The prototype approach will enable verification of process design under the range of conditions representative of larger utility boilers, but without the risks to generating equipment that would be associated with a larger full-scale boiler test program. We feel that any limitation in scaling-up the prototype results to larger boilers is far outweighed by the greater opportunities to evalute various furnace geometries, burner designs and coal properties within a reasonable budget.

(3) The multiple prototypes also provide greater opportunities to involve more utility companies, manufacturers and A&E firms directly in the development effort. We feel that maximizing the private sector involvement in this work is critical in accelerating the acceptance and application of the technology.

(4) The prototype approach will diversify the research funding to several regions of the country, thereby increasing the likelihood of outside co-funding that would be originating from local sources including state agencies, sister utility companies or other interested groups.

(5) Utilities are much more willing to make available a variety of boiler designs in this size range where the risks of performing engineering development on a larger boiler would be unacceptable or unaffordable.

We have thus far identified nine utility companies that are interested in participating in this EPRI prototype effort financially and/or hosting the tests. In addition, several state agencies have indicated an interest to participate in this work.

Despite the good prospects for broad participation and support for these prototype projects, we are still seeking additional financial support for the range of desired prototype conditions. Each prototype project is estimated to cost up to $8M, including retrofit costs and operating expenses for a one-year test program. Co-funding will be a necessity for each prototype evaluated. For the reasons outlined above, we believe that EPA participation in these prototype projects would be the most effective way to meet the goals of your program. This would create a truly national program, joining the capabilities and resources of the public and private sectors for this important objective.

We are anxious to continue our cooperation with EPA in this technology as the development efforts now begin to progress from the laboratory to the field. The increasingly larger costs associated with these efforts would seem to make this desirable for both our organizations. The recent informal technical exchanges between EPRI and EPA staff and, more recently, the plans for a jointly sponsored symposium on Dry SO2 Technology help establish the groundwork for such cooperation.

I sincerely hope that EPA will consider the opportunities of participating with EPRI and the utility industry in thes prototype projects. To provide you further details I have enclosed an information package that we have used in soliciting utility involvement.

I will be in Washington, DC on March 6 and 7 and I would welcome the opportunity of discussing this possibility with you further, if convenient to you.

Sincerely yours,

Kurt Yeager

Kurt E. Yeager
Vice President
Coal Combustion Systems Division

KEY:vbe

Enclosure

cc: A. Alm
R. Balzhiser
G. Green

Power Plant Control Technology for Sulfur and Nitrogen Oxides

| TECHNOLOGY | COMMERCIAL STATUS | APPLICABILITY | $SO_2$ & $NO_x$ REDUCTION POTENTIAL | COST (1982 $) | CRITICAL ISSUES |
|---|---|---|---|---|---|
| PRECOMBUSTION CONTROL | | | | | |
| Physical Coal Cleaning | o Commercial | o Most economically applied to coals > 1% S | o 10 to 30% S reduction | o $5/kW for flue gas conditioning<br>o $7 to 10 per ton premium (1)<br>o 0.3 to 0.45 $/MBtu (1)<br>o $400-800/ton $SO_2$ removed (7) | o Possible overall benefits<br>o Cleaning limited by pyritic S content<br>o Potential heat penalty due to increased moisture content and fines loss |
| Coal Switching and Blending | o Commercial<br>o Sufficient quantities of low S coal available for high projected demands. | o Limited to approx. 30% blending with high sulfur coal<br>o Cyclone and wet bottom boilers require low ash fusion temperature coal | o $SO_2$ reduction dependent on S content of coal.<br>o Minimum feasible emission rate approximately 1.2 lb/$10^6$ Btu | o $5/kW for flue gas conditioning<br>o 0 to $25/ton premium for low sulfur coal<br>o Costs for ESP upgrade, boiler derate, boiler auxiliaries upgrade, additional coal handling equipment, and forced outages could substantially increase cost<br>o $595-$657/ton $SO_2$ removed (6) | o Potential boiler derating due to fouling & slagging moisture content<br>o Transportation costs<br>o F.O.B. mine costs of low sulfur coal<br>o Potential ESP upgrade<br>o Potential pulverizer and coal handling equipment upgrade<br>— |
| Coal Monitors | o First commercial orders can be placed in 1984<br>o Full prototype CONAC initiated operation at TVA in 1983 | o Applicable to all coals | o None-used for coal blending and emissions | o ~$500,000 capital cost for sulfurmeter<br>o ~$600,000 capital cost for CONAC | o Little operating experience to date<br>o Prognosis favorable for future applications |

| TECHNOLOGY | COMMERCIAL STATUS | APPLICABILITY | $SO_2$ & $NO_x$ REDUCTION POTENTIAL | COST (1982 $) | CRITICAL ISSUES |
|---|---|---|---|---|---|
| COMBUSTION CONTROL | | | | | |
| $NO_x$ Combustion Control | o Low to moderate controls commercially demonstrated (LEA), OFA, BOOS, BF)<br>o Advanced low $NO_x$ burners available only for tangentially fired units. Others available by 1985 | o Retrofit options not available for cyclone and wall-fired units | o LEA - 0 to 15%<br>o BF - 5%<br>o BOOS - 20 to 25%<br>o OFA - 15 to 25%<br>o LNB - 40 to 50% | o LEA - 0 to $1/kW<br>o BF - $0/kW<br>o BOOS - $.2 to $.5/kW<br>o OFA - $1 - 2/kW<br>o LNB - $3 to $14/kW | o Several options must be available due to wide variety of boiler designs in operation |
| Furnace Dry Sorbent Injection | o Not commercially available in U.S.<br>o Full-scale demonstrations underway in Europe | o No wet bottom units<br>o Most applicable to coals with sulfur content >1% or <3.5%<br>o Low $NO_x$ burner retrofit probable | o Up to 50% $SO_2$ & $NO_x$ control | o $20 to $100/kW<br>o 8 to 12 mills/kWh for 30-yr. remaining life<br>o $650 to $1000/ton $SO_2$ removal (8) | o Process not fully understood<br>o Potential negative boiler impacts<br>o Additional particulate collection likely<br>o Potential plugging of ash handling system |
| Atmospheric Fluidized Bed Combustion | o Commercial for industrial applications<br>o 20 MW pilot plant in operation<br>o 160 MW Demo scheduled for startup in 1989 | o Wide fuel flexibility<br>o Approx. 150 boilers (20,000 MW) candidates for retrofit in U.S. | o >90% $SO_2$ removal<br>o $NO_x$ levels approx. 0.2 lb/$10^6$ Btu | o $950 to $1,080/kW (2-500 MW units-new)<br>o 99-103 mills/kWh (2-500 MW units-new)<br>o $300/KW - retrofit (5)<br>o 4.48 mills/kWh - retrofit (5) | o Fuel feed system<br>o Turndown procedure requires optimization |
| Pressurized Fluidized Bed Combustion | o No commercial operating systems<br>o Several test plants built and operating<br>o Turbocharged boiler design may precede PFBC/CC | o Offers modular siting capabilities<br>o Wide fuel flexibility | o >90% $SO_2$ removal<br>o $NO_x$ levels approx. 0.2 lb/$10^6$ Btu | o Not yet well defined; savings up to 11% expected over conventional PC/FGD plant | o Tube erosion minimization required<br>o Hot gas cleaning system needed<br>o Commercial scale gas turbine not run in a PFBC |
| Flue Gas $NO_x$ Control | o Commercial in Japan for SRC - one operating system in U.S. on oil | o Applicable to all fossil fuel generation facilities | o 80% $NO_x$ reduction for SCR<br>o 30 to 60% $NO_x$ reduction for thermal De $NO_x$ | o SCR - ~$90/kW for 80% $NO_x$ removal<br>- 12 mills/kWh for 80% $NO_x$ removal<br>o Thermal De $NO_x$<br>- $12/kWh for 50% $NO_x$ control<br>- 1 mill/kWh for 50% $NO_x$ control | o Catalyst life (SCR)<br>o $SO_3$ formation (SRC)<br>o $NH_3$ slip<br>o Heat rate penalty |

| TECHNOLOGY | COMMERCIAL STATUS | APPLICABILITY | $SO_2$ & $NO_x$ REDUCTION POTENTIAL | COST (1982 $) | CRITICAL ISSUES |
|---|---|---|---|---|---|
| POSTCOMBUSTION CONTROL | | | | | |
| Lime & Limestone FGD | o Commercial (over 60,000 MW in operation or under construction) | o Applicable to virtually all coals | o >90% $SO_2$ removal | o $175/kW (1)<br>o 18 mills/kWh (1)<br>o Retrofit costs approx. 1.1 to 1.4 times cost of new system<br>o $1000-$1200/ton $SO_2$ removed (9) | o Retrofit costs can vary widely<br>o Potential large impact on plant availability<br>o Retrofit may be constrained by space<br>o Low capacity factor or short remaining life plants uneconomic for retrofit |
| Spray Dry FGD | o Commercial<br>o 18 systems operating or planned (7500 MW) | o Applicable to virtually all coals | o ~70% $SO_2$ removal on low S coal<br>o ~90% removal indicated in short term tests on high. sulfur coal (3.5% S) | o $111/kW (3)<br>o 7.4 mills/kWh (3)<br>o $1100-$1400/ton $SO_2$ removed (9) | o Baghouse or ESP improvements may be required for retrofit<br>o Process not suitable for gypsum production<br>o Low CF or short remaining life plants uneconomic for retrofit |
| Dual Alkali FGD (Lime and Limestone) | o Commercial - three systems operating in U.S. | o Not applicable to low sulfur coal (<1.5% S)<br>o Not applicable to gypsum production | o >90% $SO_2$ removal | o $165/kW<br>o 17 mills/kWh - limestone (2)<br>o $150/kW<br>o 18 mills/kWh - lime (2) | o Limestone system difficult to control<br>o Same space and plant constraints as lime limestone FGD |
| Recovery of Salable Product FGD | o MgO (1 plant) and Wellman-Lord (2 plants) commercial in U.S. | o Applicable to virtually all coals<br>o Most applicable to sites where byproduct disposal is constrained | o >90% $SO_2$ removal | o $280/kW 19 mills/kWh MgO (2)<br>o $280/kW 26 mills/kWh W-L (2) | o Markets for products must be available<br>o Processes are relatively complicated and expensive |
| Advanced Throwaway FGD | o Weir - 4 systems in operation or under construction in U.S.<br>o Chiyoda - 2 systems in operation or under construction<br>o Saarberg-Holter 4 systems operating in Germany<br>o Co-current - several in Japan | o All applicable over wide range of coals and operating conditions<br>o Additives may be advantageous in retrofits to offset design deficiencies | o >90% $SO_2$ removal | o $140/kW 14 mills/kWh Chiyoda (2)<br>o $130/kW 16 mills/kWh Saarberg-Holter (2)<br>o $175/kW 15 mills/kWh Forced oxidation (2) | o Issues similar to these for lime and limestone FGD<br>o Little U.S. experience for most of these systems.<br>o Markets for gypsum produces (Chiyoda and and forced oxidation) need to be found |

| TECHNOLOGY | COMMERCIAL STATUS | APPLICABILITY | $SO_2$ & $NO_x$ REDUCTION POTENTIAL | COST (1982 $) | CRITICAL ISSUES |
|---|---|---|---|---|---|
| ADVANCED THROWAWAY FGD | | | | | |
| Post Furnace Dry Sorbent Injection | o Operated only at pilot scale<br>o 500 MW unit planned for late 1980s start-up | o Best suited to units in Western U.S. | o ~70% on low S coal | o $90/kW nahcolite (4)<br>o 9.6 mills/kWh<br>o $89/kW trona (4)<br>o 8.6 mills/kWh | o Sorbent availability - (Nahcolite not currently commercially mined. Trona mined in Western U.S.)<br>o Spent sorbent disposal-potential leaching of spent compounds<br>o Process fundamentals require further elucidation |

Notes:

(1) 1000 t/hr coal cleanning plant, 1982$, 30-year levelized cost basis, 40% CF, 90% availability.
(2) 2-500 MW units, 4% S coal, Midwest location, 90% $SO_2$ removal.
(3) 2-500 MW units, 0.48% S coal, Midwest location, 70% $SO_2$ removal.
(4) 2-500 MW units, 0.48% S coal, 70% removal for trona, 75% removal for nahcolite. Figures include baghouse costs.
(5) Retrofit costs based on one site-specific study only. Costs will vary considerably depending on difficulty of retrofit.
(6) However value based on switch from N. Appolachian to Central Appolachian coal; higher value based or blend of 40% Illinois Basin coal with 60% Power River Basin coal.
(7) New intensive cleaning plant (as in footnote 1) range is $400-800/ton $SO_2$ removed; upgrade an existing plant to intensive cleaning is $500-800/ton $SO_2$ removed.
(8) Based on 50% $SO_2$ removal efficiency.
(9) Does not include cost of lost generating capacity.
(10) For AFBC conversion with capital costs indicated.

DON FUQUA (Fla.), Chairman

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Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID S. JEFFERY
Minority Staff Director

April 2, 1984

William H. Podolny, Vice Pres. & Gen. Mgr.
Fuel Cell Operations
United Technology Corporation
South Windsor, Connecticut 06074

Dear Mr. Podolny:

Thank you for your testimony before the Subcommittee on Energy Develoment and Applications on March 7, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 20. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Kcw
attachment

UNITED TECHNOLOGIES POWER SYSTEMS

1825 Eye Street, N.W.
Washington, D.C. 20006
202/785-7400

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COMMITTEE ON SCIENCE
AND TECHNOLOGY

April 20, 1984

The Honorable Don Fuqua
Chairman
U.S. House of Representatives
Committee on Science and Technology
Suite 2321 Rayburn House Office Bldg.
Washington, D.C. 20515

Dear Mr. Chairman:

This is in response to your April 2, 1984 letter requesting responses to several questions. Thank you for the opportunity to provide testimony before the Subcommittee on Energy Development.

Sincerely,

Wm H Podolny
William H. Podolny
Vice President

Attachment

QUESTIONS FOR MR. PODOLNY

Question:
1. What do you expect to be the cost per kilowatt of a fuel cell powerplant at initial introduction and what is the magnitude of cost reductions you expect to be able to make through your technology development program with the Department of Energy?

Response:
The UTC electric utility fuel cell powerplant commercialization plan is based on obtaining firm commitments for a limited number of powerplants to be designed, developed, produced, installed and operated before 1990 as a controlled product and market assessment venture. Twenty-three 11 Mw units are planned for a total of 253 Mw. The first three units as prototypes will have a delivered selling price to the utilities of approximately $3,000/kW, roughly three to four times the competitive alternate. The following 20 semi-production units will have a delivered selling price on the order of $1800/kW, approximately two times the competitive alternative. Success of the venture would be achieved by customer acceptance, and placement of additional orders for delivery after 1990 in such magnitude as to provide reasonable business forecast. The estimated delivered selling price for such units manufactured on a continuous basis is between $850-$1000/kW, more or less equivalent to the competitive alternative. All of the above estimated prices are in 1983 dollars. The first 23 units are planned to be sold on a firm, fixed price basis with a certain degree of warranty. The manufacturer bears the full risk of meeting such a commitment, the utility bears the extraordinary risk associated with the first of a kind installation, and the operating costs associated with continuing future availability.

The technology development programs with the Department of Energy which should be concurrent and contiguous to the commercialization program would provide two cost improvement benefits: one would be a reduced capital cost to the utilities by improving the delivered price by 10-15% in equipment delivered after the first 23 units. The second would be reduced operating costs by reducing fuel costs through higher efficiency and by reducing maintenance and repair costs by improving system endurance and reliability, as well as, durability of components and subsystems.

Question:
2. What data of an R&D nature could be generated at a refurbished 4.8 megawatt facility at Consolidated Edison in New York that cannot be done at the existing facility in Tokyo?

Response:
The Tokyo Electric Power Company's experimental fuel cell powerplant program is soley under the control of that company. UTC provides services under contract but has no independent prerogative. There are no plans by TEPCO to modify the existing configuraion. Their plan is to operate the powerplant through December, 1984,

primarily to obtain durability, reliability and component failure rate data in addition to performance data on the machine throughout its power range. As best we understand it, there are no future plans to introduce alternate components or subsystems in a research and development effort for technology and product improvement purposes. Our recommendation is for the refurbishment and continued operation of the New York facility. The U.S. fuel cell effort needs a multi-megawatt system to generate vital information for the interested utilities; to generate component characteristics such as durability, reliability, and tolerance to operating conditions; and as an integrated configuration to evaluate constructive improvements in the host of technologies, components and subsystems that make up the integrated complex called a fuel cell powerplant.

Question:
3. You claim that United Technologies has demonstrated its ability to produce, design, fabricate, install and operate a number of fuel cell power plants. How do you justify government sponsorship in the future program?

Response:
UTC has in fact created a host of fuel cell powerplant configurations since 1965. Succeeding configurations were incremental improvements in performance or sophistication of an integrated system moving towards the objective of demonstrating the bonafide characteristics unique to the fuel cell powerplant: high efficiency of electrical generation at nominal power levels; a wide range of operation at high efficiency; a power plant that is consistent with and meets environmental constraints; a power plant that lends itself to dispersed generation and improved energy efficiency through heat recovery; a powerplant with the ability to operate on a variety of fuels; and, a powerplant which has the potential for high availability and high reliability. In each succeeding incremental step of demonstration from 4kW to 12kW to 1Mw to 4.5Mw, various technologies incroporated in components and elements critical to the fuel cell powerplant were confirmed or evaluated. Each step presented a fulcrum for the next progressive step. The result has been sufficient progress to merit the proposed venture to deploy and establish the market response. The initial commercialization venture and powerplant will introduce into the marketplace a powerplant with marginal commercially competitive characteristics at best.

The rationale for federal participation in fuel cell power plant development rests on the extraordinary contribution that the system can make to the nation's energy infrastructure. The widespread application of the technology can reduce the cost of energy service to the consumer, reduce the amount of fuel required to provide energy service, and reduce the amount of capital required to provide energy service.

The obvious benefits to the nation's economic and security interests that flow from these features are not sufficient, in their own right, to allow the introduction of the technology into the nation's utility system. Utilities have little incentive to overcome their bias for traditional equipment because they recover the cost of equipment and operation in a regulated environment. The purveyor of unorthodox equipment faces a market place that has used the same basic configuration of equipment for over seventy years. To pass through the commercial threshold, a novel generating technology must possess equivalent reliability and durability of fully mature existing systems. Without government assistance, these structural disincentives are likely to prevent the acceptance of fuel cell technology in the utility market.

Question:
4. Over what period of time do you expect continued DOE support for technology development to be necessary?

What technical or design areas require the most work?

Response:
The appropriate technology programs at DoE should be broadly focussed and directed towards customer acceptance of fuel cell power plant technology. Because phosphoric acid technology promises reduced cost of service, reduced cost of fuel, reduced capital investment, and reduced environmental impact in the near future, technology support is required through the successful operation of early commercial powerplants. Because phosphoric acid technology is a prime candidate for energy service in the transition to synthetic gas from coal in the medium term, and for energy service in the transition to fusion energy in the long term, sustaining technology support is appropriate into the indefinite future. The requirement for support of advanced concepts such as molten carbonate technology shares the same fundamental rationale for long-range support of phosphoric acid technology.

Question:
5. How much has United Technologies contributed to the development of fuel cells and over what period of time?

The support provided by United Technologies for a commercial fuel cell reseach, development, and demonstration activity has amounted to a total of $119 million through calendar year 1975 and a total of $172 million through 1983. Additional private sector support of United Technologies commercial fuel cell program by utility industry interests has amounted to $70 million through 1975 and $165 million through 1983.

DON FUQUA (Fla.), Chairman

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General Counsel
DAVID S. JEFFERY
Minority Staff Director

April 2, 1984

Robert W. Fri, Exec. Director
Fuel Cell Users Group
1101 Connecticut Avenue, N.W.
Washington, D.C. 20036

Dear ~~Mr. Fri:~~ Bob

Thank you for your testimony before the Subcommittee on Energy Develoment and Applications on March 7, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 20. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

DON FUQUA
Chairman

DF:Kcw
attachment

**THE FUEL CELL USERS GROUP**
OF THE ELECTRIC UTILITY INDUSTRY, Inc.

1301 Connecticut Avenue, NW
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Washington, DC 20036
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President
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*Executive Director*

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April 19, 1984

The Honorable Don Fuqua
Chairman
U.S. House of Representatives
Committee on Science and Technology
Suite 2321
Rayburn House Office Building
Washington, DC 20515

Dear Don:

Attached are my answers to the questions your committee raised which you forwarded to me on April 2, 1984.

If I can provide any additional clarification, I would be happy to do so.

Sincerely,

Robert W. Fri
Advisor to the Board
of Directors

RWF/lj
Enc.

## Questions for Mr. Fri

1. Your users' group suggests a five-year commitment for fuel cell research and development with a minimum of a $40 million effort in FY 1985. What do you plan for subsequent years? What would be done with this money?

Response

The Users Group has not developed specific budget recommendations for years beyond 1985, but does support a level of federal support in the out years which provides for a continuity in the program that has been lacking in proposed administration budgets in recent years. The up and down motion of the budgets as they go through the different stages in annual appropriation sequences, is both disconcerting to the contractors and the electric utility industry and prohibits long term commitments that may be dependent upon continuous federal support.

The actual federal support required will be very dependent upon the needs felt by those who are the eventual recipients of this technology, the early purchasers of fuel cell power plants. The Users Group has consistently advocated that an adequate level of funding be provided for component development and testing that will result in a power plant whose costs are competitive and whose components have been tested. We expect that the requirements for federal support will continue to be in range of recent appropriation levels for several more years.

2. Working within the Department of Energy authorization request for FY 1985, how would you restructure the funds to provide proper support for fuel cells?

Response

The Department of Energy authorization request does not provide for enough support for both the new term phosphoric acid technologies and for the more advanced fuel cell technologies at a sufficient level. If one were forced to live with a level of funding that the Department of Energy requested, it would have to be by postponing support of the more advanced technologies in order to ensure that adequate support is given to the phosphoric acid technology programs that are so near commercialization. Within the phosphoric acid program, priority should be given to the activities of the companies that are attempting to commercialize fuel cells in the near term. If this technology is not successfully brought to the market place, the longer term technologies will, more than likely, lose their support and also fail to be successfully commercialized.

3. Your testimony refers to two site-specific installation studies by utilities for 11 megawatt UTC plants. Where are the sites and who are the utilities?

Response

The two utilities that have undertaken site-specific installation studies for 11 megawatt UTC power plants are:

1. Niagara Mohawk Power Corporation - Syracuse, New York.
2. Southern California Edison - Rosemead, California.

DON FUQUA (Fla.), Chairman

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Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID S. JEFFERY
Minority Staff Director

April 2, 1984

Bernard S. Baker, President
Energy Research Corporation
Three Great Pasture Road
Danbury, Connecticut 06810

Dear Dr. Baker:

Thank you for your testimony before the Subcommittee on Energy Develoment and Applications on March 7, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 20. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

DON FUQUA
Chairman

DF:Kcw
attachment

**ENERGY RESEARCH CORPORATION**
*5 GREAT PASTURE ROAD, DANBURY, CONNECTICUT 06810 203-792-1460*
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A SUBSIDIARY OF
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April 19, 1984

The Honorable Don Fuqua
Chairman
U.S. House of Representatives
Committee on Science and Technology
Suite 2321 - Rayburn House Office Building
Washington, DC 20515

Dear Chairman Fuqua:

I want to thank you for the privilege of testifying before your Subcommittee on Energy Development and Applications, in connection with the hearings on the Department of Energy's F4 1985 Budget Authorization in Fossil Energy R&D. I have enclosed the ERC response to the additional questions submitted by your Subcommittee in your letter of April 2, 1984. I would be glad to further elaborate the response if so desired.

I would also like to take this opportunity to commend the EDA Subcommittee and Staff for their tenacity and commitment in pursuit of the appropriate Federal role in Fuel Cell R&D. We, at ERC, are particularly proud of our contributions in bringing these technologies forward, and having your Staff recognize the uniqueness and value of our Direct Fuel Cell program.

At a convenient time in your schedule, and as priorities permit, I invite you and EDA Staff to visit ERC and tour our facilities. In addition to fuel cell research, we are developing advanced batteries for electric vehicles, utility load leveling and submarine applications. I hope you will consider such a visit.

Very truly yours,

Bernard S. Baker

Bernard S. Baker
President

cc: Mr. Kripowicz, Staff Director - EDA Subcommittee

**ENERGY RESEARCH CORPORATION**

## RESPONSE TO EDA SUBCOMMITTEE QUESTIONS ON TESTIMONY BY B. S. BAKER

1. Question:

*Why are air-cooled phosphoric acid fuel cells, which you are working on with Westinghouse, "intrinsically more reliable than the earlier water-cooled plants," as you say in your testimony?*

*What advances are you now working on in these plants?*

Response:

Air-cooled fuel cells are intrinsically more reliable because they require minimal plumbing in the stack module. The water-cooled fuel cell plants require a large number of internal connectors (∿90,000 in a 7.5 MW water cooled powerplant). Even if the connector reliability was as high as 0.99999, this translates to a powerplant reliability of only 40 percent, an unacceptable level. Air-cooling also eliminates the need for complex corrosion protection and electrical isolation requirements, thus they are more cost effective, simple and highly reliable.

As I stated in my testimony, Westinghouse Corporation and Energy Research Corporation are presently developing the air-cooled plants (∿7.5 MW) for utility applications. The feasibility of air-cooling under pressurized conditions has already been demonstrated in a 10 kW size stack. Our present effort is focused on further scale up of the technology to full size stacks (from ∿10 kW to 100 kW size) and resolving some material problems related to pressurized operation. Commercial availability of this technology is anticipated in the 1988 period.

2. Question:

*In your opinion, will molten carbonate fuel cells, for which you request funding, be commercialized if phosphoric acid cells are not commercialized first? Why?*

Response:

Commercialization of molten carbonate fuel cells (MCFC) will be highly facilitated if phosphoric acid fuel cells (PAFC) are commercialized first. However, I do not believe that the commercialization of PAFC is a necessary condition for a commercialization of MCFCs. I believe that the extremely high efficiencies (50 to 60%) and simplicity would provide a significant incentive for commercialization of MCFCs, particularly the Direct Fuel Cell (DFC) version being developed at ERC. The thermal energy rejected by the plant at approx. 1150°F is a very high quality source for process heat or for powering a bottoming cycle. Envisioned markets are heavy industry and utility central station intermediate and peaking power generation. Further, the DFC offers greater flexibility in siting, less spatial allotments (over 50% reduction) compared to PAFC, and simpler operating routines and maintenance.

The two fuel cell technologies overlap in their respective applications attractiveness at the 500 to 10,000 kW levels, where the thermal energy may either be a small factor or lower grade heat streams are desirable (such as in food processing or textile manufacture). However, PAFC and MCFC have definite markets of their own that do not compete in energy requirements. The ERC DFC concept does promise to encourage scale-down to the 50 kW size, a capacity not previously thought to be within MCFC technology potentials. By eliminating the external reforming function, equipment reduction and operating simplicity make this size most attractive for small commercial and industrial use.

3. Question:

*What specifically would the requested $3 million be used for in FY 1985?*

*When would you be able to test multiple stack configurations?*

*Are you receiving funding from other sources?*

Response:

The requested $3 million funding for FY 1985 would support the component development, scale up to full size cells and verification of multicell concepts at a single cell level. Resulting from a highly successful bench-scale evaluation and test program, ERC proposes to design full scale hardware embodying the DFC benefit, namely internally reforming hydrocarbon gaseous fuels directly. The other major effort to be brought forward, is the endurance testing of DFC components at full scale. This includes multi-cell design and verifications at a single cell level.

Limited testing of multicell (or short stack) configurations at a subscale level will begin in late 1984. Full-scale stack module development is programmed for mid-1986.

ERC has been under contract to the Electric Power Research Institute (EPRI) to develop MCFCs since 1979. EPRI continues to encourage our work with about $1 million annually; ERC contributes about $0.2 million to this amount. The private sector has been cost-sharing the DFC program to approx. 30%, indicating the high regard for this innovative technology concept.

4. Question:

*Working within the Department of Energy's requested FY 1985 fuel cell program, how would you redirect money to increase the molten carbonate fuel cell budget by $1.3 million?*

Response:

The DOE FY 1985 Budget Request for the entire fuel cell program element is $13.7 million, with only $4.1 million allocated to MCFC. If sustained at this level, the programs will be catastrophically impacted.

The EDA Subcommittee, in recent years, has recognized this situation and recommended more responsive budgets. This excellent support has ensured continued significant technical progress of the several worthy fuel cell concepts, that will lead to a selection of a "best" approach in the next few years. In our opinion, the Administration's FY 85 budget request in this area does not provide any flexibility for a redirection of $1.3 million.

ERC's work in the DFC area is at a very important crossroad. We have validated our DFC concept to the satisfaction of EPRI and DOE management, that the scheme does work, and can be projected to perform properly, over a Utility- and Industry-required life with programmed preventative maintenance. To fully exploit this achievement, ERC must add engineering staff having manufacturing and production cost backgrounds to augment our technology-strong scientists and engineers in bringing this design to full scale assemblies. Our three-year program outlined in my testimony before your Committee, would result in a tested 50 kW prototype DFC stack by 1987. This is the baseline stack size for the first generation ERC system. As such, completing the R&D of this most critical component would attract additional private sector involvement and eventual commercialization of this technology.

Summarizing our position, ERC has presented a three-year program that is estimated at $16.2 million with a 25% minimum contribution already assured by the private sector.

If possible, ERC will endeavor to further increase this portion as the DFC successes attract more interest. We hope the Congress, and DOE, allow this program to move ahead at the requested pace. We feel that the funds sought for the period of 1985-1987 will provide a power generator with performance and efficiency unmatched by any other means.

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
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General Counsel
DAVID S. JEFFERY
Minority Staff Director

April 2, 1984

Fritz Kalhammer, Vice President
Energy Management & Utilization
Electric Power Research Institute
Palo Alto, California 94303

Dear Mr. Kalhammer:

Thank you for your testimony before the Subcommittee on Energy Develoment and Applications on March 7, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 20. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Kcw
attachment

EPRI
Electric Power
Research Institute

April 19, 1984

The Honorable Don Fuqua
Chairman
Committee on Science and Technology
U. S. House of Representatives
Suite 2321
Rayburn House Office Building
Washington, DC 20515

Dear Chairman Fuqua:

In your letter of April 2, 1984, you asked that I respond to several specific questions in follow-on to my testimony on fuel cell-related activities and budgets. In the following, I will attempt to answer these questions which address several of the critical issues in the development and commercialization of fuel cell power plants.

1. Will advanced fuel cell technologies (molten carbonate and solid oxide) be commercialized if the current (phosphoric acid) technology is not?

   We believe that commercialization of the phosphoric acid fuel cell over the next 5-10 years is extremely important, by itself as well as with respect to the prospects for advanced technologies, for several reasons:

   o Even today, the electric utilities have a definite need for clean, modular and energy-efficient power plants that can be sited quickly in environmentally and/or physically constrained areas; this need will become critical in the early 1990s. If developed and commercialized vigorously, the phosphoric acid fuel cell could be ready to meet this need in a cost-effective way, while none of the advanced technologies will be commercially ready by that time.

   o Several hundred millions of dollars have already been invested by a combination of Government and private sector organizations in the phosphoric acid fuel cell. If this investment fails to lead to a commercial product, it is very unlikely that the private sector will invest major efforts and funds in a yet more advanced version of a commercially untested technology.

   o Conversely, successful commercialization of phosphoric acid fuel cells will prove that the combined development efforts of Government and the private sector can lead to useful products.

   Thus, although advanced fuel cell technologies might ultimately succeed on their own merits, the inability to commercialize phosphoric acid fuel cells would almost certainly result in a long hiatus before the significant national benefits expected from fuel cells could be realized.

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*Washington Office: 1800 Massachusetts Ave., NW, Suite 700, Washington, DC 20036 (202) 872-9222*

2. Which phosphoric acid fuel cell activities will EPRI pursue in 1985 and 1986, and how do they relate to DOE's program?

Shown below are our tentative plans (subject to annual approval of our budgets by the EPRI Board of Directors and to EPRI member payments according to present projections). These plans are closely coordinated with DOE's program:

| Activity | EPRI Funds ($10^6$ $) 1985 | 1986 | Relationship to DOE Program |
|---|---|---|---|
| o Complete 4.8 MW demo | 1.0 | 0 | 50/50 cost share |
| o R&D for air-cooled 7.5 MW power plant | 1.9 | 1.6 | Coordinated tasks |
| o R&D for water-cooled 11MW power plant | 1.3 | 1.0 | Coordinated tasks |
| o Support air-cooled commercial prototype | 1.0 | 6.5 | Based upon the designs developed and verified under the R&D efforts principally funded by DOE |
| o Support water-cooled commercial prototype | 1.0 | 6.5 | |
| o Application/benefit studies | 0.3 | 0.3 | |
| o Advanced phosphoric acid technology | 0.5 | 0.4 | Total effort coordinated among GRI, NASA, DOE, DOD and EPRI |

3. Why is it necessary for DOE to continue funding the 4.8 MW demonstration?

Because the unit continues to provide a key technology learning experience and because Government partnership in this still very risky phase of development is needed to help establish the base for a subsequent program to fabricate and deploy commercial prototypes.

The 4.8 MW learning experience pertains to virtually all aspects of the technology except the fuel cell stacks (power section). Key aspects include the reformer, other fuel processing subsystems, sensors and controls, and other power plant subsystems. The 4.8 MW unit is continuing to yield important insights for needed improvements of the technology, right through the current phase of bringing the unit to the stage where operation can be attempted. Even if these attempts should prove unsuccessful, important learning experience will be gained which will influence ongoing technology improvement efforts and greatly reduce the technical risk for the commercial prototypes.

4. What are the largest obstacles to making fuel cell power plants a commercial activity?

The high cost of commercial prototypes and initial production units which will be several times higher than the cost of units in volume production.

This problem (which is encountered with any new manufactured, modular energy technology) puts the fuel cell in a "Catch 22" situation: economically attractive capital costs (say, less than $1000 per kW of capacity) will not be reached until an annual production rate of perhaps 15-20 units is achieved over a number of years to provide the required production learning and volume production benefits. On the other hand, because utilities typically are risk averse and constrained from buying equipment at non-competitive prices, they are reluctant or unable to place orders for early units. As a result, the potential manufacturer cannot rely on having a market that would justify the investments needed to establish a volume production capability--the step necessary to reduce unit costs to competitive levels.

The challenge is to break through this dilemma. EPRI's contribution to doing this is to fund part of the extraordinary costs of the commercial prototypes; $40-50 million have been set aside for this purpose in EPRI's 1985-89 budget. Another part of EPRI's strategy is to work with the Fuel Cell Users Group toward an improved understanding by the utility industry as to the applications and benefits that will justify the use of fuel cells at various cost levels.

A report dealing with the market, cost and financing issues surrounding the commercialization of fuel cells is attached.

I hope these answers will help the Committee in its deliberations. There is no doubt in my mind that the Government's fuel cell RD&D program was vital to move the technology to its present status, and that a strong and properly focussed DOE program in fuel cells remains critically important if the potentially large national benefits of this technology are to be realized.

Sincerely

Fritz R Kalhammer

Fritz R. Kalhammer
Vice President
Energy Management and Utilization

# FISCAL YEAR 1985 DEPARTMENT OF ENERGY AUTHORIZATION

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## WEDNESDAY, MARCH 7, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Development and Applications,
*Washington, DC.*

The subcommittee met, pursuant to call, at 9:30 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the committee) presiding.

Present: Representatives Fuqua, Durbin, Boucher, McCurdy, and Sensenbrenner.

Staff present: Robert S. Kripowicz, staff director; William J. Harvey, minority energy coordinator; Mr. Ratzel, professional staff; and Dan Steinway, professional staff.

Mr. Fuqua. Today is the second of 3 days of hearings on the Department of Energy's fossil fuel energy research and development budget request for fiscal year 1985. Today we will hear from three of my distinguished colleagues concerning legislation that pertains to fossil energy research and development. Subsequently, the Department of Energy's fossil energy organization will address the budget request.

It is a pleasure to welcome Nick Rahall of West Virginia, and Doug Walgren from Pennsylvania, who is a member of our committee, to testify on behalf of legislation that they have introduced. Both pieces of legislation address coal science, technology, and engineering development activities in coal. Following that, we will hear from Frank McCloskey of Indiana, who will comment on that legislation and some other fossil energy matters.

There is no question that research and development on technologies to permit clean and more efficient direct burning of coal is essential. Lack of this technology has led to underutilization of this vast domestic resource. The subcommittee is happy to hear from our colleagues and consider their recommendations on coal research.

Later, Mr. William Vaughan, the new Assistant Secretary for Fossil Energy for the Department of Energy, will speak on behalf of the Department. In addition, we welcome the much more reasonable budget request that the Department has submitted for this coming fiscal year, in comparison with previous years. That is not to say that we are entirely satisfied with the request. In several areas, particularly in fuel cells, the budget still reflects large reductions from previously congressionally approved levels.

Overall, the $273 million request is $57 million below the appropriated amounts in fiscal year 1984, and we will examine these areas of our concern during the hearing. We look forward to receiving the Department's testimony.

At this time, I would like to submit a statement for the record from Mr. Winn and Mr. Sensenbrenner.

[The opening statements of Mr. Winn and Mr. Sensenbrenner follow:]

## OPENING STATEMENT BY THE
## HONORABLE LARRY WINN, JR.

SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
HEARING ON FY 1985 DOE AUTHORIZATION REQUEST FOR FOSSIL ENERGY

MARCH 7, 1984

THANK YOU MR. CHAIRMAN. I ALSO EXTEND MY WELCOME TO MR. VAUGHAN, THE NEW ASSISTANT SECRETARY FOR FOSSIL ENERGY. WE LOOK FORWARD TO WORKING WITH MR. VAUGHAN AND HOPE OUR RELATIONSHIP CAN BE MUTUALLY SATISFACTORY.

FIRST, I WOULD LIKE TO SAY THAT THE FY 1985 AUTHORIZATION REQUEST FOR FOSSIL ENERGY IS A VERY SATISFACTORY DOCUMENT FROM SEVERAL STANDPOINTS. IT CERTAINLY IS MORE RESPONSIVE TO THE WILL OF CONGRESS, AS INDICATED BY PREVIOUS AUTHORIZATION AND APPROPRIATION LEVELS, THAN EARLIER REQUESTS. ALSO, THE BUDGET REQUEST APPEARS TO BE VERY ADEQUATE FOR MAINTAINING RESEARCH AND DEVELOPMENT PROGRAMS IN THE BROAD SCOPE OF THE FOSSIL ENERGY PROGRAM. NEXT, I BELIEVE THAT WE HAVE MADE A VERY SATISFACTORY TRANSITION FROM OUR PILOT PLANT AND DEMONSTRATION PLANT IDEAS OF SEVERAL YEARS AGO TO OUR PRESENT RESEARCH AND DEVELOPMENT-ORIENTED PHILOSOPHY. SO I FIRMLY SUPPORT THE BUDGET, BOTH IN CONTEXT AND IN CONTENT.

On the other hand, I want to extend to DOE the option of flexibility. It may be that, since this budget was created, DOE has been faced with technical breakthroughs or program re-evaluations. If such is the case and DOE wants to restructure the fossil energy program or to provide new priorities, I will be glad to work with the Department accordingly.

One last feature of the fossil energy budget relates to the decision by the Congress to establish manpower floors. I realize that this action was probably caused by lack of communication several years ago. However, I do believe this is a tendency by the Congress to manage DOE programs. It would be very appropriate for Congress to drop this manpower floor concept, leaving the management of the DOE programs up to DOE. I think we must assume that, given the responsibility, DOE will adequately manage their programs within the funds provided by Congress. In a recent interview, Peter Grace, in reviewing the report to the President of the private sector survey on cost control, claimed that the Department of Energy is probably the best managed agency in the federal sector.

Mr. Chairman, I appreciate this opportunity to make these comments and we look forward to hearing from Mr. Vaughan.

# OPENING STATEMENT

HONORABLE F. JAMES SENSENBRENNER, JR., (R-WIS)

EDA SUBCOMMITTEE HEARING ON
DOE FOSSIL PROGRAMS
FOR FY85
MARCH 7, 1984

THANK YOU, MR. CHAIRMAN, FOR THIS OPPORTUNITY TO EXTEND A WELCOME TO OUR COLLEAGUES, THE HONORABLE NICK J. RAHALL, THE HONORABLE DOUG WALGREN, AND THE HONORABLE FRANK MCCLOSKEY, WHO SHARE INTEREST AND CONCERN OVER THE DEVELOPMENT OF THIS COUNTRY'S FOSSIL RESOURCES, AND THE THE ASSISTANT SECRETARY FOR FOSSIL ENERGY, WILLIAM VAUGHAN.

I LOOK FORWARD TO OUR WITNESSES' TESTIMONY THIS MORNING ON THE FOSSIL ENERGY PROGRAMS CONDUCTED BY THE DEPARTMENT OF ENERGY.

THE ADMINISTRATION HAS REQUESTED A REDUCTION IN THESE PRO-

GRAMS FOR THE FISCAL YEAR 1985. WHILE THE FOSSIL ENERGY PROGRAMS ARE REDUCED BY 17.2 PERCENT FROM FY84 LEVELS, MUCH OF THE REDUCTION IS IN CONFORMITY WITH THE RECENT ERAB REPORT ON THE FEDERAL ROLE IN ENERGY RESEARCH AND DEVELOPMENT.

MR. CHAIRMAN, IN ANALYZING THE ADMINISTRATION'S REQUEST, WE MUST REJECT THE ARBITRARY NOTION THAT UNLESS IT MEETS THE FY84 LEVELS IT IS INHERENTLY BAD AND MUST BE REJECTED. IF THIS WAS OUR POLICY, NO RESEARCH PROGRAM COULD EVER REACH ITS LOGICAL CONCLUSION. INSTEAD, WE MUST SCRUTINIZE THE REQUEST TO ASCERTAIN WHETHER IT ESTABLISHES CONTINUNITY IN OUR RESEARCH EFFORTS AND MAXIMIZES OUR LIMITED FINANCIAL RESOURCES.

IN THIS EFFORT, YOUR THOUGHTS, AS WELL AS THOSE CONTAINED IN THE ERAB REPORTS ISSUED ON THESE PROGRAMS ARE ESSENTIAL IF WE ARE TO EFFICIENTLY UTILIZE OUR LIMITED FINANCIAL RESOURCES.

I LOOK FORWARD TO HEARING YOUR THOUGHTS ON THESE PROGRAMS.

Mr. FUQUA. Now we will hear from our distinguished colleague from West Virginia, Mr. Rahall. Nick, we are very happy to have you here this morning. I know of your longstanding interest in fossil fuel, and the support that you have given us over the years, and the interest that you have expressed in making fossil fuel, particularly coal, a more viable part of our fuel alternatives. We are happy to have you with us today.

## STATEMENT OF HON. NICK J. RAHALL, A U.S. REPRESENTATIVE FROM THE STATE OF WEST VIRGINIA

Mr. RAHALL. Thank you, Mr. Chairman. I do deeply appreciate the opportunity to testify before your committee. I do not believe I could have picked a more favorable body in this Congress to appear before to make a case for coal research and development programs. You have been very favorable in the past, you have been very helpful in the past, and time and time again this subcommittee has taken up the cause of advanced coal technologies, and I commend you for this diligence. On behalf of all of us in West Virginia who are seeing some exciting new technologies being advanced in this industry, we appreciate your support, and we thank you for that.

We are on the verge of some exciting new technological breakthroughs in advanced coal combustion and utilization methods. This is especially important in consideration of the Nation's options to meet electrical load growth. These advanced technologies are also necessary for coal to meet our more stringent environmental standards.

In the foreseeable future, it appears that coal will continue to fire the majority of this country's electric utility boilers. However, in the age of uncertain demand for electricity I would suggest that smaller coal-fired powerplants will be preferred by utility management because, as a recent OTA study stated, they have shorter lead times, lower financial risk, and greater public acceptance than current nuclear designs.

With this in mind, and given the increased desire and need to burn coal in an environmentally sound manner, fluidized bed boiler designs appear to be the ideal size to meet this criterion. In this light, I am particularly pleased with the proposed utility-scale TVA atmospheric fluidized bed demonstration plant. The facility would generate 160 megawatts at a cost of 10 to 20 percent less than conventional plants with scrubbers while meeting strict air quality standards.

Another example of what I view as new technology which will be part of the cutting edge in cleaner coal burning is chemical coal washing. Chemical washes in the future should be able to remove not only pyritic, but also much of the organic sulfur in coal, and I envision the day when chemical washes will enable lower sulfur coals to meet new source performance standards without post-combustion cleanup devices.

There is clearly a pressing need, Mr. Chairman, for such advances in coal technology. Currently, the most dominant technology-based pollution control method in use is the flu-gas desulfurization, more commonly known as scrubbers.

Most plants using scrubbers rely on "wet" systems which remove sulfur dioxide with limestone. It is a costly technology, ranging from $169 to $429 per kilowatt to retrofit and $1,000 per kilowatt to build a new plant with scrubbers, and it has some adverse environmental consequences in the form of sludge, which is costly to store and to treat. According to the Department of Energy, a typical 500 megawatt powerplant with a wet scrubber will need a 400-acre 40-foot deep sludge disposal pond.

In the near future, fluidized bed combustion, chemical coal washes, and retrofittable technologies such as LIMB will prove to be more economical and environmentally sound than scrubbers. On the advanced technology front, we can expect MHD and fuel cells to provide great benefits. Compared to these methods, scrubbers are a technological dinosaur.

Today, as you consider DOE's fiscal year 1985 authorization and the possibility of a multiyear DOE authorization bill, I would like to discuss legislation which I have introduced, H.R. 4182, the National Coal Science Technology and Engineering Development Act.

The goal of this bill is to accelerate the development of new and advanced coal technologies under a comprehensive research program. However, rather than creating a separate new program of research and development, H.R. 4182 would build upon, refocus and accelerate relevant on-going activities in DOE's coal program.

Many of the provisions of H.R. 4182 are based on information from a number of hearings held by this subcommittee on coal research, and at this time I would like to express my appreciation to the several members of the subcommittee who have been most helpful in the formation and in the information that have been provided for this bill: Congresswoman Marilyn Lloyd, Congressman Paul Simon, Congressman Rick Boucher who is with us at this hearing this morning, and Richard Durbin, members of this subcommittee who are cosponsors of H.R. 4182. I am also delighted to be joining with my colleague from Pennsylvania, Mr. Doug Walgren, also a member of this committee, and I look forward to working with him very closely as we develop the concept involved in H.R. 4182.

Those major elements are the establishment of a 5-year program to accelerate the development of a range of technologies to promote the use of coal in an environmentally acceptable manner. The program would focus on three areas.

## COAL SCIENCE

This would be a comprehensive effort to understand coal structure and process chemistry. Of particular concern would be an understanding of how to efficiently and effectively remove pollutants from coal.

Process science engineering is another area. This would be a comprehensive research program to develop new and advanced technologies for coal preparation, with emphasis on chemical coal cleaning; specification fuels, such as coal liquid mixtures; precombustion cleanup of flue gases; and advanced coal utilization processes, including retrofittable technologies for the removal of sulfur and nitrogen oxides, fluidized bed combustion, fuel cells, gas turbines, and MHD.

There is also a provision in this section of the bill to establish an ongoing center for cooperative research with industry and universities on fluidized bed combustion. Naturally, I would envision such a center to be located at West Virginia University. This university has been conducting research on fluidized bed combustion for over 20 years, and it is currently involved in establishing a cooperative relationship with industry for sponsorship of this type of research. So you can see, it is not just the fact that it is in my home State. I might also add that WVU is located near the Morgantown Energy Technology Center, which is the lead center for fluidized bed research at the Department of Energy. And it is very near to the home area of my good friend, Doug Walgren, Pittsburgh, PA.

### ENGINEERING DEVELOPMENT

This would be an effort carried out in conjunction with the private sector. The program would be directed to establish proof of concept and produce within 5 years processes and coal systems at a scale large enough to permit ready commercialization by the private sector. It would involve significant cost sharing between the Federal and non-Federal participation for the demonstration of various technologies.

### A SECOND SECTION

The Assistant Secretary for Fossil Energy would be responsible for administering the program, which would be carried out through the energy technology centers, the national laboratories, the university community, and the private sector.

Three, the bill would require the preparation of a 5-year research plan, which would show how the program is to achieve the objectives of the bill, in addition to an annual and a final report to ensure effective technology transfer.

Four, the program would be authorized at $775 million over a 5-year period. This funding would be incremental over current levels for the coal program.

One of the most important aspects of this legislation, Mr. Chairman, is its attempt to couple proof of concept with the commercialization stage through demonstration and pilot projects. Frankly, the administration's expectation that the private sector will undertake the process development stage has proven to be fallacious. It is the same song and dance that we have heard in so many different areas from this administration.

The payoff from the large investments necessary for many of these projects is a decade or more away, and as such are not competitive with near-term investment options and needs. In addition, in most instances, these projects are not driven by predictable and specific market requirements and must be undertaken in an uncertain regulatory environment. For example, the Clean Air Act can change every 4 years, and a given technology can become obsolete before a return from that technology is ever realized.

Because of this situation, I strongly believe that it is in the national interest of the Federal Government to assume a role in bringing advanced coal technologies to the commercialization stage. In this regard, the engineering development program of H.R. 4182 is aimed at demonstrating the technology at a scale large enough to permit ready commercialization with funds appropriated on a cost-sharing basis between the Federal Government and non-Federal participants.

These projects are listed in the bill and address three basic types of coal-use technologies: the precombustion treatments, the inherently low polluting combustion processes, and the postcombustion cleanup.

Mr. Chairman, with your permission, I would ask that the legislation be inserted in the record. As already noted, this is a 5-year program. The timeframe was chosen because of the renewed interest in coal R&D due to the debate on acid rain. It is my view and one supported by a great deal of the scientific evidence that it will take at least an additional 5 years before we know sufficient facts, before we know the causes, and before we know the effects of acid deposition to warrant the consideration of any massive control legislation.

However, the available options for achieving emission reductions on existing prenew source performance standards sources, if justified by the research being conducted on acid deposition, are limited and consist of either mandating scrubbers or allowing utilities to switch to lower sulfur fuels. The former option, as I mentioned earlier, is very expensive and has some adverse environmental consequences, and the latter option has the potential of causing unemployment in the high-sulfur coal regions of our Nation.

There is a way out of this scrubbing/switching dilemma, and I believe the program envisioned by my legislation is a vehicle for preventing policies which will render large segments of the Nation's coal reserves unmarketable and put thousands of additional coal miners out of work. The bottom line is that it is essential that our options for controlling emissions be increased before seeking more stringent standards on existing sources of sulphur and nitrogen oxides.

As this subcommittee develops a multiyear DOE authorization, it may want to consider the general thrust and provisions of H.R. 4182. I also ask respectfully, Mr. Chairman, that you take into account the fact that the fossil energy budget of DOE, as you have mentioned, has been slashed by 76 percent between fiscal year 1981 and fiscal year 1984. At present, there remains an inequity between the administration's proposed $1.1 billion for nuclear R&D and then $202.7 million suggested for fossil R&D in fiscal year 1985.

Again, I express my appreciation to this subcommittee for its support in the past and for its very diligent effort in regard to fossil R&D. I thank you, Mr. Chairman.

[The prepared statement of Mr. Rahall follows:]

# Statement of Hon. Nick J. Rahall

## Subcommittee on Energy Development and Applications

## FY85 Authorization for DOE's Fossil Energy and Research Program

March 7, 1984

Mr. Chairman, members of the Subcommittee. I could not have picked a more favorable body in the Congress to appear before to make a case for coal research and development programs. Time and time again, this subcommittee has taken up the cause of advanced coal technologies and you are to be commended for this diligence.

We are on the verge of some exciting new technological break-throughs in advanced coal combustion and utilization methods. This is especially important in consideration of the Nation's options to meet future electrical load growth. These advanced technologies are also necessary for coal to meet more stringent environmental standards.

In the foreseeable future, it appears that coal will continue to fire the majority of this country's electric utility boilers. However, in an age of uncertain demand for electricity, I would suggest that smaller coal-fired powerplants will be preferred by utility management because, as a recent OTA study stated, they have shorter leadtimes, lower financial risk and greater public acceptance than current nuclear designs.

With this in mind, and given the increased desire and need to burn coal in an environmentally sound manner, fluidized bed boiler designs appear to be the ideal size to meet this criteria. In this light, I am particularly pleased with the proposed utility-scale TVA atmospheric fluidized bed demonstration plant. The facility would generate 160 megawatts at a cost of 10% to 20% less than conventional plants with scrubbers while meeting strict air quality standards.

Another example of what I view as new technology which will be part of the cutting edge in cleaner coal burning is chemical coal washing. Chemical washes in the future should be able to remove not only pyritic, but also much of the organic sulfur in coal, and I envision the day when chemical washes will enable lower sulfur coals to meet New Source Performance Standards without post-combustion cleanup devices.

There is clearly a pressing need for such advancements in coal technology. Currently, the most dominant technology-based pollution control method in use is Flu Gas Desulfurization, more commonly known as scrubbers.

Most plants using scrubbers rely on "wet" systems which remove sulfur dioxide with limestone. It is a costly technology--ranging from $169 to $429 per kilowatt to retrofit and $1,000 per kilowatt to build a new plant with scrubbers--and has some adverse environmental consequences in the form of sludge which is costly to store and treat. According to DOE, a typical 500 megawatt powerplant with a wet scrubber will need a 400-acre, 40-foot deep, sludge disposal pond.

In the near future, fluidized bed combustion, chemical coal washes and retofittable technologies such as LIMB will prove to be more economical and environmentally sound than scrubbers. On the advanced technology front, we can expect MHD and fuel cells to provide great benefits. Compared to these methods, scrubbers are a technological dinosaur.

Today, as you consider DOE's FY85 authorization and the possibility of a multi-year DOE authorization bill, I would like to discuss legislation which I have introduced, H.R. 4182, the "National Coal Science, Technology and Engineering Development Act."

The goal of this bill is to accelerate the development of new and advanced coal technologies under a comprehensive research program. However, rather than creating a separate new program of research and development, H.R. 4182 would build upon, re-focus and accelerate relevant on-going activities in DOE's coal program.

Many of the provisions of H.R. 4182 are based on information from a number of hearings held by this Subcommittee on coal research, and at this time, I would like to express my appreciation to Marilyn Lloyd, Paul Simon, Rick Boucher and Richard Durbin--members of this Subcommittee who are cosponsors of H.R. 4182.

The major elements of H.R. 4182 are as follows:

1) The establishment of a five-year program to accelerate the development of a range of technologies to promote the use of coal in an environmentally acceptable manner. The program would focus on three areas.

Coal Science: This would be a comprehensive effort to understand coal structure and process chemistry. Of particular concern would be an understanding of how to efficiently and effectively remove pollutants from coal.

Process Science and Engineering: This would be a comprehensive research program to develop new and advanced technologies for coal preparation with emphasis on chemical coal cleaning; specification fuels such as coal liquid mixtures; pre-combustion cleanup of flue gases; and advanced coal utilization processes including retrofittable technologies for the removal of sulfur and nitrogen oxides, fluidized bed combustion, fuel cells, gas turbines and MHD.

There is also a provision in this section of the bill to establish an ongoing center for cooperative research with industry and universities on fluidized bed combustion. Naturally, I would envision such a center to be located at West Virginia University. This university has been conducting research on fludized bed combustion for over 20 years and is currently involved in establishing a cooperative relationship with industry for sponsorship of this type of research. I would also add that WVU is located near the Morgantown Energy Technology Center, which is the lead center for fluidized bed research in DOE.

Engineering Development: This would be an effort carried out in conjunction with the private sector. The program would be directed to establish proof-of-concept and produce within five years processes and coal systems at a scale large enough to permit ready commercialization by the private sector. It would involve significant cost-sharing between the federal and non-federal participants for the demonstration of various technologies.

2) The Assistant Secretary for Fossil Energy would be responsible for administering the program which would be carried out through the energy technology centers, the national laboratories, the university community and the private sector.

3) The bill would require the preparation of a five-year research plan which would show how the porgoram is to achieve the objectives of the bill in addition to annual, and a final report, to insure effective technology transfer.

4) The program would be authorized $775 million over a five-year period. This funding would be incremental over current levels for the coal program.

One of the most important aspects of this legislation is its attempt to couple proof-of-concept with the commercialization stage through demonstration and pilot projects.

Frankly, the Administration's expectation that the private sector will undertake the process development stage has proven to be fallacious.

The payoff from the large investments necessary for many of these projects is a decade or more away and as such are not competitive with near-term investment options and needs. In addition, in most instances these projects are not driven by predictable and specific market requirements and must be undertaken in an uncertain regulatory environment. For example, the Clean Air Act can change every four years and a given technology can become obsolute before a return is ever realized.

Because of this situation, I strongly believe it is in the national interest for the federal government to assume a role in bringing advanced coal technologies to the commercialization stage.

In this regard, the Engineering Development Program of H.R. 4182 is aimed at demonstrating a technology at a scale large enough to permit ready commercialization with funds appropriated on a cost-sharing basis between the federal government and non-federal participants. These projects are listed in the bill and address the three basic types of coal use technologies: pre-combustion treatments, inherently low-polluting combustion processes and post-combustion cleanup.

Mr. Chairman, with your permission, I would ask that H.R. 4182 be included in the record.

As already noted, H.R. 4182 is a five-year program. This time-frame was chosen because of the renewed interest in coal R&D

due to the debate on "acid rain." It is my view, and one supported by a great deal of scientific evidence, that it will take at least an additional five years before enough is known on the causes and effects of acid deposition to warrant the consideration of control legislation.

However, the available options for achieving emission reductions on existing pre-NSPS sources--if justified by the research being conducted on acid deposition--are limited and consist of either mandating scrubbers or allowing utilities to switch to lower sulfur fuels. The former option as I mentioned earlier is very expensive and has some adverse environmental consequences, and the latter option has the potential to cause unemployment in high-sulfur coal regions.

There is a way out of this scrubbing-switching dilemma, and I believe the program envisioned by H.R. 4182 is a vehicle for preventing policies which will render large segments of the Nation's coal reserves unmarketable.

The bottom-line is that it is essential that our options for controlling emissions be increased before seeking more stringent standards on existing sources of sulfur and nitrogen oxides.

As this Subcommittee develops a multi-year DOE authorization, it may want to consider the general thrust and provisions of H.R. 4182. I also ask that you take into account the fact that the fossil energy budget at DOE has been slashed by 76 percent between FY81 and FY84. At present, there remains an inequity between the Administration's proposed $1.1 billion for nuclear R&D and the $202.7 million suggested for fossil R&D in FY85.

Thank you.

Mr. **Fuqua**. Thank you very much, Nick. If you have time, we will hear from our colleague, Mr. Walgren, and then we probably will have some questions.

Mr. **Rahall**. Mr. Chairman, I do have a commitment to sit in for my subcommittee chairman on the mines and mining subcommittee of Interior as we do our budget recommendations this morning. I do apologize.

Mr. **Fuqua**. I certainly understand. Let me just say that I think you have a very constructive bill. Particularly in your statement about scrubbers, I think scrubbers is probably one of the most inefficient uses. While we are trying to clean up the environment, it creates more problems than it solves in waste, as you very well pointed out. I hope that we can develop the fluidized bed and other means where we can eliminate the need for scrubbers and the problems it creates. In addition, I think that many of the oil-fired plants that we have, particularly on the east coast, can be switched to coal, using the same kind of steam generators and the other equipment without having to build a new plant. It would save the utility customers a considerable amount of money. Rather than having to close the plant down, they can convert from oil to coal, using something like a fluidized bed. I certainly hope we can get moving on it.

Do any of the members of the subcommittee have any questions?

Mr. **Sensenbrenner**. Mr. Chairman, I ask unanimous consent that an opening statement of mine be inserted in the hearing record and yield back the balance of my time.

Mr. **Fuqua**. Without objection, the statement will follow that of Mr. Winn.

Mr. **Boucher**. Mr. Chairman, I would like to commend Mr. Rahall for bringing this legislation forward, and I am pleased to serve as a cosponsor of it. I certainly think that you make a good point, Nick, when you say that new coal cleaning technologies can replace scrubbers, and I sincerely hope that this committee can give greater emphasis to those coal-cleaning technologies as we review the department's request this year.

I noticed that you mentioned chemical coal cleaning as a preference to the use of scrubbers. I would hope that you would be in a position to agree that physical coal cleaning can be important as well. I know in my congressional district, we have two research projects underway today that are developing enhanced flotation processes, the goal of which is to reduce the ash and sulphur content rather dramatically. While these are not chemical processes, I think they are very promising.

I would hope that as we look at your legislation, you would be amenable to an amendment that would emphasize physical coal cleaning as well as chemical cleaning.

Mr. **Rahall**. If I might respond, Rick, I would certainly agree that that is a good suggestion and a good addition to the legislation you have joined me in cosponsoring. I would be very amenable to that idea.

Mr. **Durbin**. I must confess to the subcommittee that I am somewhat taken aback. When Mr. Rahall asked Mr. Simon and me to cosponsor this, he indicated that the university facility would be in

Illinois. Now this morning to suggest that he is moving it to West Virginia, we may have to reconsider, Nick. This is news to us.

On a more serious note, I have followed this whole question of the future of coal fairly closely, being from a district in Illinois which is second only to Paul Simon's in terms of the number of coal mines. It has the two largest coal shaft mines in the world. We are concerned about sulfur content or looking for opportunities, and I think this bill points in that direction.

I would like to share with you, though, something that has come to light over the last several months, which puts a new cast on the use of coal. We are now working with the Synthetic Fuels Corporation on a project that envisions taking the Illinois high-sulfur coal and, through the Texaco gasification process, converting it into ammonia gas and then into anhydrous ammonia fertilizer, using as a seed stock basic high-sulfur coal instead of natural gas, with a considerable savings to the farmer at the end of the process.

This opened my eyes to a new attitude toward the use of our coal, and I would hope that as this bill progresses—and I will be more than happy to help you with it—that we at least leave room in the mandate given within the bill for some new applications and new technologies. As I said, this came as news to me that it even could be done. Now that it is very clear that it can be done, I think we as a nation should look into it. If we need any further incentive, other than our vast coal resources, to explore such things as this coal gasification resulting in fertilizer, we have only to look to our friends in Japan, who again are 60 days away from breaking ground on a plant that will do exactly the same thing, using the Texaco gasification process. The Japanese are going to transport coal from British Columbia to Japan, convert it into anhydrous ammonia fertilizer, and sell it around the world.

If they can turn a profit using this procedure, think of what this can do in our farm bill in our own farming areas. So the potential is there, and I think your bill is a step in the right direction. I commend you for sponsorship, and I am happy to cosponsor it, even if the university ends up being in West Virginia.

Mr. RAHALL. If I may respond, Mr. Chairman, I certainly appreciate the comments of the gentleman from Virginia, Mr. Boucher, and the gentleman from Illinois, Mr. Durbin. Their cosponsorships have been most helpful to me, and their suggestions here this morning for the new technologies with which they have personal experience in their congressional districts. Those will be helpful in the final formation of this legislation.

We are concerned about how to advance the burning of coal in an environmentally sound manner. Mr. Chairman, you have mentioned the savings to the utilities. Yes, that is what we are talking about also. We are talking about savings to the consumer, who will be the ultimate payer of these technologies. It is our common desire to ensure that he or she does not face higher utility bills decades from now to find that we really have not improved our environment that much. So we are looking at consumer-oriented legislation, as well as legislation to improve this Nation's energy security posture.

Mr. FUQUA. I want to point out to you and to Mr. Durbin, in case there is any problem about where this research could be done, maybe a neutral site like Florida would be a good place because we are very interested in coal. We are one of the big users of it.

Thank you very much, Nick, we appreciate your being here this morning.

Mr. RAHALL. Thank you, Mr. Chairman. I again express my appreciation to my colleague from Pennsylvania, Mr. Walgren, for yielding for me to go first. I know that he is a member of this committee, and I again thank him for that.

Mr. FUQUA. We are very pleased now to welcome our colleague, Congressman Doug Walgren, who is also chairman of the Subcommittee on Science, Research and Technology on this committee. I know he has had a long and continuing interest in coal and coal technology. As a matter of fact, the committee has visited in Pittsburgh and the energy center that is located there, and I know of his longstanding interest in that.

Doug, we are happy to welcome you here this morning. I know you have introduced a bill that is similar to the one Mr. Rahall has introduced, and we are happy to have you today. You know you will get a good reception.

## STATEMENT OF HON. DOUG WALGREN, A U.S. REPRESENTATIVE FROM THE STATE OF PENNSYLVANIA

Mr. WALGREN. Thank you very much, Mr. Chairman.

I have introduced a similar piece of legislation. I think that we will all wind up cosponsoring each other's in this area because it is an area of such importance. I would like to think that in Nick's absence this morning, we might just shift the location of these projects north 30 miles, which would not be a very dramatic change in anything, but I am sure that this committee will work out the ways to have the best facilities, the best mines, and the best collection of efforts focused on coal research as we work our way through this area.

I would simply like to make two points, both of which would be addressed in Mr. Rahall's bill and the other bills in this area and also in mine. The first is that we really need a stable commitment to coal research. This technology and the resource has such potential for solving and really making the future of America literally bright that it is a shame to see us go forward in a willy-nilly fashion, cutting and pulling and hauling on these coal research budgets.

The fact is that it is the most abundant energy resource, at least in the nonnuclear sense, that we have. In Pennsylvania alone, we have literally several hundreds of years of supplies for the energy demands of the country as a whole. That must mean that when you add up Illinois and West Virginia and everything else, we just have a tremendous supply here. It is only a technological problem of access to this wonderful energy content that lies in this coal, in an environmentally positive way. Knowing the advance of science and simply looking at the portrait of the chairman on the wall, you would have to know that these problems will be solved in the next decade, and that this will be a resource that is very available to the magic of our minds. It is only a question of assembling the resources to do it.

Since 1981, we know what has happened to coal research budgets. In the Pittsburgh Energy Center, they have been reduced literally $3 for every $4 that was being spent, not in the engineering or in the demonstration phase but in the actual basic research phase of the programs that we had in coal research in this country. The Congress has been sensitive and tried to resist, but the reality of the limitations on Government, as driven by this administration's policies, have devastated the effort in coal research. That is just plain not in the national interest.

I would like to underscore how important I think it is that we do get on a 5-year commitment. As Mr. Rahall and others, I, too, in my proposal—and I hope all our proposals—will set out a 5-year plan with substantial funding. We are suggesting $750 million, as are the others, over a 5-year period. That would not bring these efforts even to the levels that they were implemented during the 1976 to 1980 period. But nonetheless, clearly if you are serious about this business, you have to talk about setting up funding on a stable 5-year basis, and certainly that is the least we should do if we are to be in pursuit of the national interest in this area.

I think we have to look back and see the damage that has been done by the uncertain and reduced funding that these programs have had over these years and know that we ought to be putting such a stable, adequately funded and future authorization in place so that we can pursue developments in this area.

The second point I would like to make, Mr. Chairman, is to underscore what has been widely recognized, both in hearings in my committee, in this committee, in the Commerce Committee, and in the people who are commenting about public policy in this area. That is that we have literally at present a gap between the basic research that can possibly be funded by our Government through the Department of Energy and the implementation of the developed technology, the "mature" technology that the Synthetic Fuels Corporation is authorized and charged with the responsibility of enabling to happen.

In between those two levels is a barrier that, if left unaddressed, is simply going to kill any development in that area. So we want, as Mr. Rahall's bill does and as the other proposals and mine does too, to target substantial moneys for demonstration. It is a very simple fact that the private industry is not ready to take the risk to commercialize this technology on a commercial scale, given the possibilities of drops in oil prices, the fact that our energy prices are still not within our domestic control, and that these technologies are still in areas where we have much to find out. Even the fluidized bed project at Georgetown University can deliver us so much technical knowledge that is necessary for a private firm to really rely on a certain configuration of a similar plant to operate effectively on a commercial scale.

We need to be supporting those demonstration projects so that we can get the technical run, the information from the technical runs, out of the pilot projects and the like. If we do not do that, I think reasonable people would agree that the actual commercialization will simply just not happen. I know in my area in Pennsylvania there is a project in Homer City on gasification, where there has been interest from the private sector to join in the cost to make the runs, to do the processing, and gathering of the data that would be the key to commercialization, but the Government is just unwilling to join in that process, even on a cost-sharing basis. Therefore, again, it just will not happen.

We provide and suggest that we ought to be spending certainly $200 million over the next 5 years for process science and engineering development and $500 million in the later stages of engineering development. I just think that reasonable people will agree that if you do not embark on that kind of a program, we are not going to be safeguarding, let alone contributing, to the national interest over the next several decades.

I hope that we can sort of bootstrap our political sensitivity and consciousness by looking back on the two areas of our economy that have benefited so much from active participation of Government funding and research. This Nation leads the world in aerospace and in agriculture, and the common thread between those two areas is that we have had a tradition, literally, of substantial involvement of Government funding, not in an adversary way, but on a cooperative way and in a way which heavily involves the private sector. If we do not bring the same kind of pragmatic approach to what is necessary to do and what we have to do together, again, these areas just will not happen.

I appreciate the chance to come before the committee and make those two points. I would like to have my written statement submitted for the record that perhaps does it better. But I really appreciate the interest that your committee, Mr. Chairman, has brought to coal research. If it were not for the interest of this committee in these last several years, I do not think we would have anything. We do at least have a base from which we can start, and if we approach this sensitively, putting aside the regional differences in our country, I know this committee will find a way to rise above the parochial interest of the individual members that we might have, and the Nation's interest will be served in that process.

Thank you very much.

[The prepared statement of Mr. Walgren follows:]

### PREPARED STATEMENT OF CONGRESSMAN DOUG WALGREN

Thank you, Mr. Chairman. I appreciate this opportunity to testify before your subcommittee this morning. I'd like to recognize the leadership of the gentleman from West Virginia, not only on this particular subject, but for his effectiveness in the Congress of the entire range of issues which involve coal.

I am here to testify today because I believe that *America's greatest hope for achieving independence from foreign oil supplies* lies in our vast supply of coal resources. Coal is an abundant, inexpensive and domestic solution to our energy needs, with reserves sufficient to power the nation for several hundred years. Reserves in Pennsylvania alone total 31 billion tons, or an equivalent of 136 billion barrels of crude oil.

Yet, despite the promise of coal, its potential continues to go unrealized. Increased and focused research by the federal government is the key to realize that potential in the new term. Most research on coal focuses on its use as a synthetic fuel or on new ways of using coal, with the intent of increasing efficiency and lowering emissions. Coal from the Eastern part of the country tends to be high in sulfur, yet also is higher in heating content. Development of new coal technologies is vital to be able to take advantage of the high energy content of coal mined east of the Mississippi and at the seme time, to meet environmental standards.

After the oil embargo of a decade ago, the government made a strong commitment to funding coal research. But, since 1981 the present Administration has repeatedly attempted to dismantle the federal effort to increase coal use. At the same time, these dollars have been used to increase funding on atomic weapons, to the point where atomic defense activities would make up 62 percent of the proposed 1985 DOE budget.

While Congress has acted each year to partially restore the Administration's funding cuts, the constant uncertainty about future of funding has made effective coal research difficult, if not impossible. Last year's funding request for coal research reflected a 90% cut from 1981 levels. While this year's budget reflects some increase in appreciation of the value of coal research by the Administration, coal research is still down significantly from the level set by the Congress last year. President Reagan proposes to cut coal liquefaction by 52%, surface coal gasification by 59%, fuel cells by 68%, and MHD by 41%.

As a consequence of these repeated funding cuts and restorations, coal research has been uncoordinated and focused on the short-term, neglecting the more extensive long-term research necessary to develop effective new technology. The proposal I have introduced addresses this problem by providing a *stable level of funding over a five year period.* With a five-year plan from the Department of Energy, along with annual reports on the progress of the Department in meeting its goals.

The second area I want to emphasize to the Committee is what has become known as the "gap" in technology development. As the President of the Synthetic Fuels Corporation recently testified before the Energy and Commerce Committee, "the Corporation does believe a gap exists between the assistance available from the Department of Energy for basic research and that available from the Corporation for the commercial production of synthetic fuels." He went on to caution that this gap would "become a problem for the second and third generation technologies expected to be developed within the decade."

This "gap," between basic research on the one hand, and full commercialization on the other, is a *consequence* of the Reagan Administration's policy to completely *withdraw from any role in demonstrating technology or establishing proof-of-concept of new and advanced technologies.* With the SFC restricted to funding commercial projects which have been adequately demonstrated, and DOE limited to research, it was left to private industry to fill in the middle. Unfortunately, with falling oil prices, industry has not been willing or able to do so.

Clearly, it is unrealistic to expect private industry to finance demonstration projects costing tens of millions of dollars when the expected product may not be competitive with $29 per barrel oil. When oil prices rise again, or when shortages reoccur, we will need these technologies to be ready for full-scale implementation.

My legislation addresses the problem by providing for a *cost-sharing program* initiated by proposals from the private sector, for technologies in the stage of engineering developing. Upon application by private sector parties, federal funds would be available to share in the cost of establishing proof-of-concept and developed processes in any of thirteen areas.

I certainly want to encourage the committee to explore a number of approaches to this program. But, I believe if we ignore it, we will continue to see the increasing ability of other nations to adopt basic technology begun in the U.S. and commercialize it—to the point where they have the potential to sell that technology back to the United States. In several fields, such as coal-water mixtures and photovoltaics, the U.S. has done the basic R&D, only to see the technology developed commercialized abroad. Initial research dollars invested in magnetohydrodynamics (MHD), fuel cells, and other fields have established a technological field other nations are only too eager to capture for themselves.

Finally, Mr. Chairman, I can't help but comment on the fact that there are really two areas where the United States has commanded leadership throughout the world—*aviation and agriculture.* The common thread of both these areas is the traditional acceptance of strong government funding in research. We have the knowledge, the experience, and the resources to lead in coal research. I hope we don't let this opportunity slip.

I look forward to working with you and the Committee on this issue.

98TH CONGRESS
2D SESSION

H. R. ______

IN THE HOUSE OF REPRESENTATIVES

Mr. WALGREN (for himself, Mr. Murphy, Mr. Kolter, ____________________) introduced the following bill; which was referred to the Committee on ____________

# A BILL

To establish a national coal science, technology, and engineering development program.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the ''National Coal Science, Technology, and Engineering Development Act of 1984''.

FINDINGS AND PURPOSES

SEC. 2. (a) The Congress makes the following findings:

(1) There is significant potential for the vast domestic coal resources of the United States to play an increasingly important role in the Nation's energy future. These coal resources, in particular peat and anthracite coal, have been and remain greatly underutilized.

(2) Increased coal use is dependent upon establishing a foundation in coal science that will be the basis for all activities leading to process and engineering development and the commercial application of advanced technologies and systems that are consistent with the Nation's environmental goals.

(3) An inadequate foundation in coal science, process science, and engineering development is limiting current efforts to exploit the Nation's vast coal resources.

(4) There must be an accelerated and focused effort to develop and introduce into the marketplace improved and advanced technologies that limit the emissions of sulfur dioxide, nitrogen dioxides, toxic trace elements, and particulate matter which result from coal

utilization. Such efforts must include a broad range of technology options that include pre- and post-combustion treatment, along with combustion modifications, and new and improved utilization technologies to limit sulfur and nitrogen oxide emissions. Waste solid and liquid treatment and disposal must be considered in these technologies to avoid negative environmental impacts.

(5) Current environmental control capabilities must be improved by reducing capital and operating costs and preserving and improving the overall availability of coal-fired powerplants.

(6) Changes in the domestic economy and changes in environmental requirements, coupled with rapid changes in the supply and price of oil and gas resources, have created significant economic disincentives which preclude the private sector from sustaining a stable long-term research and development program that will enhance expanded coal use. In recent years, both private and Federal support for coal-related research and development has declined substantially. If allowed to continue, this decline could limit the future availability of coal which can be utilized in an environmentally acceptable manner.

(7) Coal research and development programs in universities and industry tend to focus on the short

term due to the lack of adequate funding and tend to be focused on projects with a near-term payback. As a consequence, these efforts generally do not include the more extensive longer term research necessary to develop significant technological improvements or breakthroughs which can enhance the utilization of the Nation's vast coal reserves in an environmentally acceptable manner.

(8) The current thrust of the ongoing Federal coal research and development program is too diverse and is not directed to establishing proof of concept of new and advanced technologies and systems at an engineering-scale size in a timely fashion. This has constrained the timely transfer of technology which, in turn, has constrained the expanded use of coal.

(9) A credible and productive Federal coal research and development program must be defined and sustained for many years. Such a program must be adequately funded, insulated from short-term political and market fluctuations, sufficiently broad in scope to produce results, and executed in cooperation with both the university community and the private sector.

(10) It is in the national interest for the Federal Government, through its energy technology centers and research contracts with industry and universities, to play a leadership role in accelerating coal science,

technology, and engineering development, and to accelerate the development of more efficient and cost-effective conventional and advanced coal utilization and emission control technologies.

(b) The purposes of this Act are to--

(1) promote and significantly expand the use of the full range of the coal resources of the Nation in an environmentally acceptable manner by accelerating research and development in basic coal science and the development and commercial application of more efficient and cost-effective coal utilization technologies and systems; and

(2) expand federally sponsored research and development in a manner that permits a comprehensive, totally integrated, and clearly focused coal research and development program to be implemented in cooperation with the university community and the private sector by establishing a national coal science, technology, and engineering development program.

## ESTABLISHMENT OF PROGRAM

SEC. 3. (a) The Secretary of Energy is directed to carry out a national coal science, technology, and engineering development program as provided in this Act. The program shall be administered by the Assistant Secretary for Fossil Energy through the energy technology centers.

(b) The national coal science, technology, and engineering development program shall consist of the following three research and development programs:

(1) The coal research program as provided in section 4.

(2) The process science and engineering research program as provided in section 5.

(3) The engineering development program as provided in section 6.

COAL RESEARCH PROGRAM

SEC. 4. (a) The purpose of the coal research program shall be to conduct research, for all coal ranks, that seeks an indepth understanding of coal structure and process chemistry. The program, which shall be conducted in a manner that recognizes the unique physical and chemical properties of each individual rank of coal, shall be directed toward the understanding of how pollutant species are bound in the coal molecule and how such species can be efficiently and effectively removed.

(b) The coal research program shall be--

(1) performed by the energy technology centers, the national laboratories, the university community, and the private sector; and

(2) administered by the Assistant Secretary for Fossil Energy through the energy technology centers.

## PROCESS SCIENCE AND ENGINEERING RESEARCH PROGRAM

SEC. 5. (a) The purpose of the process science and engineering research program shall be to conduct research that is applicable to all coal ranks and that recognizes each individual rank of coal, in the following areas:

(1) COAL PREPARATION.--Development of new processes that pulverize coal to extremely fine particles, allow for separation of ash and pyrite particles from the coal, and remove ash, pyrite, and organic sulfur to levels consistent with environmental and equipment uses.

(2) SPECIFICATION FUELS.--Development of ready-to-use and fully characterized transportable coal fuels (for example, coal liquid mixtures) that are suitable for use in various equipment such as boilers, furnaces, and combustion engines. These fuels are to be economically competitive with oil and gas.

(3) PRECOMBUSTION CLEANUP.--Development of new and improved technologies that can clean coal-derived gaseous and liquid fuels prior to use, particularly gas streams at high temperatures, and remove deleterious materials that create pollutants or adversely impact equipment usage. Such technologies shall include necessary supporting analytical and control equipment.

(4) POSTCOMBUSTION CLEANUP.--Development of new and improved processes that will remove sulfur, nitrogen,

toxic trace elements, and ash constituents that result in deleterious emissions. Emphasis shall be given to those processes that are regenerable and will reduce the quantity and improve the quality of disposable byproducts associated with sulfur dioxide scrubbing systems. This effort shall include improvements in state-of-the-art scrubbers to increase system availability and reduce costs. Emphasis shall also be given to processes that can reduce nitrogen oxide emissions and capture particulates and to combined processes for multiple pollutant removal.

(5) UTILIZATION PROCESSES.--Improvement, modification, and development of new processes and equipment that will permit utilization of coal or coal-derived fuel such that pollutant formation and release is well below environmental limits and the resulting integrated system is cost competitive both in terms of capital costs and operational costs. Technologies to be pursued include--

(A) direct combustion of coal for utility, industrial, commercial, and residential applications;

(B) magnetohydrodynamics (MHD);

(C) atmospheric and pressurized fluidized-bed combustion;

(D) other combustion (in situ) pollution control technologies;

(E) fuel cells;

(F) diesel engines; and

(G) gas turbines, using environmentally acceptable liquids from coal.

(6) INSTRUMENTATION AND CONTROL.--Reduction of system operating costs and improvement of system availability by developing new sensors and control systems that will enhance the commercial application of coal utilization technologies and systems.

(7) SOLIDS TRANSPORT.--Reduction of capital and operating costs associated with coal and coal-solids handling by developing a detailed fundamental knowledge of the movement of solids.

(8) SUPPORTING RESEARCH AND DEVELOPMENT.--Characterization of the various liquids and solid wastes generated by the use of coal, development of processes that will assure the disposal of such wastes in an environmentally acceptable manner, and development of processes that facilitate the cost-effective recovery of raw materials from coal utilization wastes. Materials research shall be conducted to ensure that advanced process concepts can be supported with available engineering materials.

(b) The process science and engineering research program shall be--

(1) performed by the energy technology centers, the national laboratories, the university community, and the private sector; and

(2) administered by the Assistant Secretary for Fossil Energy through the energy technology centers.

ENGINEERING DEVELOPMENT PROGRAM

SEC. 6. (a) The purpose of the engineering development program shall be to carry out projects under subsection (b), by making grants to eligible applicants, in order to establish proof of concept and produce developed processes and coal systems.

(b) The Secretary of Energy, working through the Assistant Secretary for Fossil Energy, shall make grants to eligible applicants for any one or more of the following projects:

(1) constructing and operating a fine coal preparation and cleaning process facility of no more than 500 tons per day capable of testing both physical and chemical coal cleaning devices and processes;

(2) retrofitting and testing an oil-fired boiler of at least 100 MWe (megawatts electricity) using deeply, physically, or chemically cleaned coal, or any combination of such types of cleaned coal;

(3) demonstrating a regenerable flue gas desulfurization system of at least 50 MWe;

(4) demonstrating a combined SOX (sulfur dioxide)/NOX (nitrogen oxides) removal system of at least 50 MWe;

(5) conducting and testing a retrofit of in-boiler sulfur control technology of at least 50 MWe;

(6) demonstrating an atmospheric fluidized bed combustion system of at least 100 MWe;

(7) demonstrating a repowering application of a pressurized fluidized bed combustor of from 50 to 100 MWe;

(8) demonstrating a repowering application of combined cycle coal gasification of from 50 to 100 MWe;

(9) developing and testing a coal-fueled gas turbine in a second generation combined-cycle system of at least 50 MWe;

(10) developing and testing an industrial-scale coal-fueled gas turbine suitable for industrial cogeneration of at least 5 MWe;

(11) testing a utility phosphoric acid fuel cell system using coal-derived gas at a size of 10 to 50 MWe;

(12) demonstrating engineering feasibility of magnetohydrodynamics (MHD) technology at a size of 10 to 50 MWe; and

(13) demonstrating an advanced coal liquefaction process of at least 5 to 10 tons of coal per day.

(c) The engineering development program shall be administered by the Assistant Secretary for Fossil Energy through the energy technology centers. A grant may be made under this section only upon application by an eligible applicant at such time, in such manner, and containing such information as the Assistant Secretary for Fossil Energy deems necessary.

(d) A grant made under this section may be used to pay for only a portion of the total cost of an approved project, in an amount deemed appropriate by the Assistant Secretary for Fossil Energy.

(e) An ''eligible applicant'' under this section means any entity other than a Federal Government entity.

## FIVE-YEAR PLAN

SEC. 7. (a) As a part of the national coal science, technology, and engineering development program, the Secretary of Energy, with the cooperation of the Assistant Secretary for Fossil Energy, shall prepare a five-year national coal science, technology, and engineering development research plan. The plan shall include--

(1) identification and definition of the near- and mid-term opportunities for expanding the use of coal in the industrial, electric utility, and other sectors of

the economy;

(2) a detailed description of the specific activities which have been, or will be, developed by the Department of Energy to address these opportunities and carry out the mandates of this Act;

(3) a statement and explanation of specific priorities and objectives, timetables for achieving such objectives, and a research strategy for achieving such objectives and the mandates of this Act; and

(4) a detailed description of the resource requirements for the implementation of the plan, and a description of the manner in which those resources will be deployed.

(b) The plan shall be submitted by the Secretary of Energy to the President and the appropriate committees of Congress within six months of the date of enactment of this Act.

## ANNUAL AND FINAL REPORTS

SEC. 8. (a) At the end of each of the five fiscal years beginning after the date of enactment of this Act, the Secretary of Energy shall submit an annual report to the President and the appropriate committees of the Congress. The report shall include a detailed description of the national coal science, technology, and engineering development program and activities undertaken for that fiscal year, and the achievements and progress toward the objectives defined in the five-year plan pursuant to this Act.

(b) Within 90 days of the end of the fifth fiscal year beginning after the date of enactment of this Act, the Secretary of Energy shall submit to the President and the appropriate committees of Congress a report identifying the achievements of the program, and identifying and defining further research needs and opportunities for promoting the expanded use of coal.

### AUTHORIZATIONS

SEC. 9. (a) There are authorized to be appropriated to the Secretary of Energy for the coal research program for fiscal years beginning after September 30, 1984, $75,000,000, to be available to the Secretary through fiscal year 1989.

(b) There are authorized to be appropriated to the Secretary of Energy for the process science and engineering program for fiscal years beginning after September 30, 1984, $200,000,000, to be available to the Secretary through fiscal year 1989.

(c) There are authorized to be appropriated to the Secretary of Energy for the engineering development program for fiscal years beginning after September 30, 1984, $500,000,000, to be available to the Secretary through fiscal year 1989.

Mr. **Fuqua**. Thank you very much, Doug. Let me say that I agree wholeheartedly with you. We started several years ago—and you were part of the committee at that time—having some demonstration projects. Those have been phased out very rapidly in the last few years because of the change in philosophy of the administration that private industry would pick these things up.

As you pointed out very eloquently, private industry has not moved in to pick these up. Even the utilities must get bond ratings and so forth, and the bond market will not change to something that is new and untried and maybe has not been proven on a commercial scale.

We have spent a considerable amount of money and investment in time and talent, trying to develop some of these technologies, but yet we have failed in that last very important step, to demonstrate it in a scaled up version so that it will work. I think you point out a very important thing, and energy is what oils the economy.

We are fat and happy right now because oil prices have been depressed. It makes alternative energy sources less competitive if you compare it on today's price. But then when you look at the political situation in the world and what can happen very rapidly should there be an embargo or something happen that could interrupt world oil supply, and the United States is involved with the other Western nations, we would be in a very catastrophic situation.

It seems to me that now is the time. Regardless if oil is 25 cents per barrel, we need to move forward to develop these alternatives. If anybody thinks we are going to have a continuous and unlimited supply, they must be smoking something or a great dreamer.

I was at a breakfast this morning where the chairman of the Agriculture Committee was saying how he was on a nuclear submarine, and he asked the captain how long could he stay underwater. He said, "It's classified, but basically it's how much food we have." The point was that American agriculture is going to determine how long a nuclear submarine can stay underwater.

Also our economy is dependent upon energy. We cannot have agriculture if we do not have energy to grow the agricultural commodities. As Mr. Durbin was pointing out, the fertilizer, anhydrous ammonia, a source of nitrogen, is very important. It is essential. So we do have a stake, and I think we are dragging our feet and not moving forward like we should.

I want to thank you for your statement today. I wholeheartedly agree with you. Mr. Boucher?

Mr. **Boucher**. Thank you, Mr. Chairman. I, too, would like to commend Mr. Walgren for bringing this legislation forward.

I was somewhat concerned, looking over the bill, to note that the demonstration project for coal and water mixtures, which is included in Mr. Rahall's bill, was not included in yours. Was that an oversight? Do you have some particular reason for leaving it out, and would you be amenable to suggestions to reinsert it?

Mr. **Walgren**. I would like to talk to folks about that. One of the thrusts in my developing this legislation was to try to give greater flexibility to the people who may be in a better position to decide exactly which project to carry out, at what time. Therefore, I tried not to specifically name project after project. I do not feel that I am in a position to know enough about that to be able to write that into law.

I also tried to take, in my bill, a page from the Synthetic Fuels Corporation in emphasizing cost sharing and initiatives proposed by the private sector for cost sharing. I think there is magic in this private sector, and I certainly think we ought to maximize the direction that they can give us because their signals are very sound signals. I tried to be a little less specific in my bill to allow those who know more about the technologies and the immediate potential, the near-term potential, to bring one project on at a time when it might contribute its most and perhaps not be required to go immediately to the spending of resources on another at that time.

Mr. BOUCHER. I would only respond by saying that I find these technologies to be enormously promising. Just as we are doing research in my congressional district today on coal cleaning technologies, we are also working on coal and water mixtures. But these technologies have not reached the demonstration stage yet, and I would think that as we specifically target particular areas for an increased emphasis in fossil fuel research, through your legislation or Nick Rahall's, that we should be looking at these technologies which are so promising and which can rapidly accelerate the conversion of industries and utilities from oil to coal. I think the coal and water mixture is certainly in that category, and I would hope that we could reinclude it as we look at your legislation.

Mr. WALGREN. It certainly is not intended to be left out. That is for sure.

Mr. BOUCHER. Let me say, though, that I commend you for including physical coal cleaning in your bill. As I indicated to Mr. Rahall when he testified, that had been omitted from his legislation. I think, again, that is a very promising approach which we should emphasize.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you very much, Doug. We appreciate your being here.

At this point, I would like to insert a statement on behalf of our colleague, Mr. Frank McCloskey, from Indiana.

[The prepared statement of Mr. McCloskey follows:]

STATEMENT OF THE HONORABLE FRANK MCCLOSKEY (8TH DISTRICT-INDIANA) BEFORE THE HOUSE SCIENCE AND TECHNOLOGY SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS IN SUPPORT OF H.R. 4182.

MR. CHAIRMAN, I APPRECIATE THIS OPPORTUNITY TO SUBMIT TESTIMONY IN STRONG SUPPORT OF H.R. 4182, THE NATIONAL COAL SCIENCE, TECHNOLOGY, AND ENGINEERING DEVELOPMENT ACT. THIS LEGISLATION WILL ESTABLISH A FIVE YEAR PROGRAM TO ACCELERATE THE DEVELOPMENT OF NEW AND ADVANCED TECHNOLOGIES TO ALLOW FOR THE EXPANDED USE OF COAL IN AN ENVIRONMENTALLY ACCEPTABLE WAY. IT ALSO PROMISES TO EXPAND THE USE OF HIGH SULFUR COAL IN INDUSTRIAL PROCESSES. ENACTMENT OF H.R. 4182 WILL REVERSE THE DANGEROUS TREND OF DISINVESTMENT IN COAL RESEARCH WHICH WE HAVE SEEN OVER THE LAST FOUR YEARS. IT WILL GREATLY ASSIST US IN ACHIEVING OUR NATIONAL GOAL OF COMPLETE ENERGY INDEPENDENCE AND IN SO DOING ENHANCE OUR OWN NATIONAL SECURITY.

H.R. 4182 CALLS FOR A NEW PARTNERSHIP AMONG THE GOVERNMENT, COAL INDUSTRY, AND UNIVERSITIES WHICH CAN LEAD US TO A BRIGHTER AND MORE SECURE ENERGY FUTURE FOR OUR COUNTRY. MR. CHAIRMAN, I BELIEVE THAT THIS LEGISLATION IS ONE OF THE MOST SIGNIFICANT ENERGY INITIATIVES WHICH THE CONGRESS CAN UNDERTAKE. APPROVAL OF H.R. 4182 WILL SERVE OUR IMMEDIATE AND LONG-TERM NATIONAL INTERESTS BY KEEPING OUR NATION ON THE CUTTING EDGE OF THE COAL TECHNOLOGY CURVE.

ALMOST 13 YEARS BEFORE THE OPEC OIL EMBARGO, CONGRESS ESTABLISHED THE OFFICE OF COAL RESEARCH. THANKS TO THE PERSISTENT EFFORTS OF SENATOR ROBERT BYRD OF WEST VIRGINIA, WE KNEW THEN WHAT WE MUST RELEARN NOW. COAL IS THE ANSWER TO PRACTICALLY ANY ENERGY DILEMMA WHICH OUR COUNTRY CAN FACE.

IT IS THE ONLY ENERGY RESOURCE FOUND IN ABUNDANCE IN THE MIDWEST. INDIANA COAL RESERVES ARE ESTIMATED TO BE OVER 17 BILLION TONS, RECOVERABLE BY CURRENT METHODS. AT OUR PRESENT RATE OF PRODUCTION, INDIANA COULD MINE HIGH-SULFUR, HIGH BTU VALUE COAL FOR THE NEXT 500 YEARS! BY ONE METHOD OF CONVERSION, THIS RESERVE EQUATES TO 60 BILLION BARRELS OF OIL.

BUT JUST AS THE MIDWEST HAS AN ABUNDANCE OF COAL, THE COAL IN THE MIDWEST IS HIGH IN SULFUR CONTENT. OFFSETTING THIS ENVIRONMENTAL DISADVANTAGE IS THE HIGHLY DESIRABLE ENERGY PROPERTY OF THIS TYPE OF COAL FOUND IN ITS HIGH BTU VALUE WHEN BURNED. TO TAKE ADVANTAGE OF THIS PROPERTY, OUR RESEARCH AND DEVELOPMENT EFFORTS WITH THE OBJECTIVE OF COMMERCIALIZATION OF VARIOUS TECHNOLOGIES MUST BE ENHANCED. IT CERTAINLY CANNOT OCCUR WITHIN THE CONTEXT OF THE CURRENT ENERGY BUDGET SUBMITTED BY THE PRESIDENT.

WHILE NUCLEAR FISSION RESEARCH HAS RECEIVED TOP PRIORITY BY THE ADMINISTRATION, COAL RESEARCH AND DEVELOPMENT HAS BEEN PUT ON THE BACK BURNER. SOME WOULD SUGGEST IT ISN'T EVEN ON THE STOVE. PRESIDENT REAGAN INHERITED AN FY 1981 BUDGET REQUEST OF $1.135 BILLION FOR FOSSIL FUEL RESEARCH. THIS YEAR, HE HAS SUCCEEDED IN CUTTING BACK THE PROGRAM BY 76 PERCENT, TO $273 MILLION OVER FOUR YEARS. IN THE MEANTIME, NUCLEAR FISSION RESEARCH HAS REMAINED AT AROUND $1 BILLION OVER THE COURSE OF THE ADMINISTRATION'S ENERGY PLANS. MR. CHAIRMAN, THIS IS ENERGY IMBALANCE. IT DOES NOT PROMOTE THE USE OF COAL OR ADDRESS THE PRESENT OR FUTURE PROBLEM OF UNEMPLOYMENT IN THE COAL FIELDS. IT IS UP TO US TO ENACT THE BYRD-RAHALL COAL SCIENCE PROGRAM TO PUT OUR NATION'S ENERGY PRIORITIES IN ORDER.

MR. CHAIRMAN, THERE IS ROOM TO CUT THE ADMINISTRATION'S NUCLEAR ENERGY REQUEST AND SUBSTITUTE IN ITS PLACE THE BUDGET NECESSARY FOR H.R. 4182. AS THE COMMITTEE KNOWS, THE COAL SCIENCE BILL WE ARE SUPPORTING WOULD REQUIRE $775 MILLION OVER FIVE YEARS, OR ABOUT $155 MILLION IN ADDITIONAL FOSSIL FUEL RESEARCH ANNUALLY. IF ADDED TO THE BUDGET THIS YEAR, WE WOULD STILL BE OPERATING AT FAR LESS THAN 50% OF THE FOSSIL FUEL RESEARCH ACCOUNT SUBMITTED IN FY 1981. SO, MR. CHAIRMAN, THIS LEGISLATION IS CLEARLY A BUDGETARILY RESPONSIBLE APPROACH TO TAKE AND IS CLEARLY WITHIN THE MEANS OF THE GOVERNMENT TO FINANCE.

JUST WHAT KIND OF PROGRAM DO WE ENVISION WITH THE IMPLEMENTATION OF H.R. 4182? IT IS A PROGRAM DEDICATED TO EXPANDED COAL SCIENCE, PROCESS SCIENCE AND TECHNOLOGY, ENGINEERING DEVELOPMENT AND WORK THROUGH ENERGY TECHNOLOGY CENTERS, AND RESEARCH CONTRACTS WITH INDUSTRY AND UNIVERSITIES TO ACCELERATE THE DEVELOPMENT OF ADVANCED COAL COMBUSTION TECHNOLOGIES. THESE TECHNOLOGIES INCLUDE, BUT ARE BY NO MEANS LIMITED TO, PROCESSES OF MAGNETOHYDRODYNAMICS (MHD) ATMOSPHERIC FUEL BED (AFB) AND PRESSURIZED FUEL BED (PFB) COMBUSTION, LIME-INJECTION COMBUSTION, COAL GASSIFICATION, COAL PRE-COMBUSTION TECHNOLGOIES SUCH AS THOSE UTILIZING MICROBES TO BREAK THE MOLECULAR BONDS BETWEEN THE ORGANIC SULFUR AND CARBON TO PRODUCE AND EXTRA-ORDINARILY CLEAN BURING HIGH SULFUR COAL WHILE RETAINING ITS HEATING VALUE. MANY OF THESE PROCESSES ARE ALREADY WELL ALONG IN THE LABORATORY AND IN DEMONSTRATION. HOWEVER, TO BRING THEM TO COMMERCIALIZATION AND SCALE-UP WITHIN THE NEAR FUTURE WILL REQUIRE THE PLAN WHICH H.R. 4282 REPRESENTS.

MR. CHAIRMAN, THOUSANDS OF COAL DIRECT-HIRE AND INDIRECT-HIRE JOBS ARE PRESENTLY HANGING IN THE BALANCE AS THE ECONOMY WINDS ALONG THE PRECARIOUS PATH OF RECOVERY. HUGE DEFICITS AND HIGH INTEREST RATES PREVENT THE EXTENDED TYPE OF APPLIED RESEARCH AND DEVELOPMENT VENTURE CAPITAL NECESSARY FOR ROBUST R & D COAL RESEARCH PROGRAMS BY THE PRIVATE SECTOR. H.R. 4182 IDENTIFIES THE PROPER ROLE OF THE DEPARTMENT OF ENERGY AND PROVIDES RESOURCES NECESSARY TO THE FEDERAL GOVERNMENT TO UNDERTAKE THE LEVEL OF EFFORT COMMENSURATE WITH THE IMPORTANCE OF COAL TO OUR NATION'S ECONOMY AND SECURITY. I HOPE THAT THE COMMITTEE WILL BE ABLE TO TAKE FAVORABLE ACTION ON H.R. 4182 IN THE NEAR FUTURE.

**Mr. Fuqua.** Now we will hear from Mr. William Vaughan, Assistant Secretary for Fossil Energy, U.S. Department of Energy.

Mr. Vaughan, we are very pleased to have you here today. You have a prepared statement, and we will make that in its entirety a part of the record. If you wish to summarize, we would be pleased to hear from you.

## STATEMENT OF HON. WILLIAM A. VAUGHAN, ASSISTANT SECRETARY FOR FOSSIL ENERGY, U.S. DEPARTMENT OF ENERGY, ACCOMPANIED BY DONALD BAUER, PRINCIPAL DEPUTY ASSISTANT SECRETARY FOR FOSSIL ENERGY; AND J.E. WALSH, JR., DEPUTY ASSISTANT SECRETARY FOR MANAGEMENT, PLANNING, AND TECHNICAL COORDINATION

**Mr. Vaughan.** Thank you very much, Mr. Chairman and members of the subcommittee. I am pleased to be here today.

As you have already indicated, I would like to submit my formal statement for the record and take only a few minutes with some brief opening remarks before turning to questions of you and the rest of the members of the committee.

As you have noted, sir, this is my first appearance before the subcommittee as the Fossil Energy Assistant Secretary. In many ways, however, I am returning to the fossil energy family, particularly the coal side of it. Prior to joining the Department of Energy, I was the corporate energy manager of one of this country's and the world's largest industrial coal users. I am proud to say that we were one of the leaders within industry in terms of applying new technological options for the use of coal in particular and fossil fuels in general.

Now, upon returning to the area of fossil energy, I am equally pleased to return to the challenges and opportunities offered by research and development. Furthermore, I am pleased to tell you that I bring with me in this reorganization the Strategic Petroleum Reserve and the Naval Petroleum and Oil Shale Reserve Programs, thus consolidating in one office the fossil fuel assets of the Department of Energy.

At this time, of course, the concepts have a much more distant time horizon and a much higher risk of success or failure, and that makes them appropriate for federally sponsored research. I might also say at this point, Mr. Chairman, that my month-long association with the Fossil Energy Office has brought me into contact with a solid group of hard-working professionals. Two of them are seated at the table with me today. On my right, Mr. Don Bauer, my principal deputy, and on my left, Mr. Jerry Walsh, the Deputy Assistant Secretary for Management in the Fossil Program. Others are seated immediately behind me, and they are here this morning to be ready to answer your more detailed questions, if necessary. As the "new boy on the block," I can assure you, gentlemen, that I will not attempt to give you the impression that I am intimately familiar with the variety of these programs. I wish that I were at this stage, but it would not be candid to so state. Therefore, if you go into details, as you may well wish, I will call upon my colleagues to help me.

Furthermore, I have not had the chance yet to visit a number of the sites that we operate. I want to assure this committee that I come from a tradition of "hands on" and I do want to get out to those locations, not only those that we operate in the department but a variety of those in the private sector, so that I can get some hands-on knowledge of what is going on out there in our own facilities and in the private sector.

Let me also say at the outset, Mr. Chairman, that I have been impressed with the diligence and hard work of the staff of this subcommittee. The briefings we have held in this past month or 6 weeks, and the questions and answers that we have provided to the staff prior to this hearing have shown me that the committee is one of the most knowledgeable in Congress. It is thorough and has caused us lots of hard work to dredge those answers up for them.

I look forward to establishing a solid working relationship with you and members of this committee and the staff in the weeks and months to come.

Turning now to the subject of your hearing, the fiscal year 1985 budget, we believe we have put before you a technologically sound, fiscally responsible and well-balanced budget proposal. One of the major themes woven throughout the fabric of this budget is an attempt to address the intent of Congress in proposing a viable, productive fossil energy research and development program. As I stated on page 3 of my prepared statement, when budget proposals differ from congressional appropriations by a factor of three as they have in the past, programs are admittedly disrupted, projects proceed in a stop/start fashion, and the value of the programs to the Nation is, admittedly, diminished. I certainly do not want to be a part of that sort of thing.

We have made a genuine attempt in the preparation of this budget this year to change. Now I recognize that our budget request is some $274 million for fiscal year 1985 and still below the level of the fiscal year 1984 appropriations. But we have narrowed the gap to something on the order of 15 percent or so. As a result, I believe our discussions this year can focus on fine-tuning the content of our program in a conversational, rather than a confrontational, manner. I assure you that we in the department do not intend to confront this or other committees of the Congress over this program.

Another theme in our budget proposal is its consistency with the national energy policy plan. Having viewed fossil energy from the perspective of both industry and, in the last several years, Government, I readily agree with projections of the policy plan that as much as 70 percent of our energy will continue to come from fossil fuels well into the next century.

It is incumbent upon us, therefore, to position future generations for the continued use of these fossil fuels, and to do so in a way that does not erode our economy or compromise our national environmental values. That is where new technology comes into the picture.

One of the two strategies of the national energy policy plan is to promote a balanced and mixed energy resource system. Quite simply, we do not have one today. We are still too dependent on those fuels we have in least supply, and not enough dependent on those that are most abundant. If we are going to change that mix in the future, we need to improve the competitiveness of coal in markets that are today dominated by oil and gas.

The programs we have proposed in this budget will help us do that. They will give industry the technological options that will enable them to view coal in the same competitive light as they do oil and gas—from the perspective of handling and transporting it to the perspective of burning it or converting it cleanly and efficiently.

I might say at this point, Mr. Chairman, that there is a strong recognition within this budget that direct combustion will continue to be the dominant use of coal for well into the foreseeable future. This means that we must continue to address the fundamental obstacles to coal burning, and those are primarily environmental.

The theme of environmental compliance runs throughout this budget. For example, programs that can have a direct bearing on reducing acid rain precursors, such as $SO_x$ or $NO_x$ or particulates, account for more than $57 million of our coal budget or about one-third of it. The comparable funding level for 1984 was just under $37 million, and the $20 million increase we are proposing is a major component of the President's commitment, expressed in his State of the Union address, to increase acid rain related efforts.

The subject of acid rain is, of course, a controversial one. It is occupying the daily activities of a number of people within the administration and within the Congress. I do not mean at this point to try to sort out the conflicts and the uncertainties that permeate this issue, but I do see it as incumbent upon us within the fossil energy program to view the problem from the standpoint of various technical alternatives.

I also must tell you that we are not the lead organization in conducting acid rain research within the Federal Government, but we do have the lead role within the Department to develop potential technological options that industry can use in the future when the need arises.

Let me describe one initiative in particular that is driven by environmental considerations. We have proposed $5.2 million in 1985 to investigate innovative approaches for the control of acid rain precursors in the flue gas of existing coal-fired powerplants. We are proposing in the fiscal year 1985 budget to issue a competitive procurement in the flue gas cleanup area.

We want industry to propose ways of cleaning the gases released by coal-fired powerplants, perhaps at a more modest level than is done today, but certainly at much lower cost. The technology would be retrofittable to those plants that are currently not required to install scrubbers but may have to in the future.

Our rationale is this: Today, utilities investing in scrubbers have the option of purchasing a system capable of 90 percent sulfur dioxide removal but at a cost of perhaps as much as $900 to more than $1,000 per ton of sulfur removed.

If legislation is passed requiring older plants—those not now covered by the Clean Air Act—to reduce emissions by, say, 50 percent, utilities do not have much choice but to purchase a scrubber that is more effective and much more costly than they really need. Or, they might choose to bypass that convenient, nearby high-sulfur coal mine in favor of a low-sulfur mine 1,000 miles away. Or, they might shut the powerplant down altogether.

We think utilities need another technological option. So we are looking for scrubber concepts that would offer a minimum of 50- to 60-percent sulphur dioxide control at a maximum cost of $500 per ton of $SO_2$ removed.

The funding for this procurement, $5.23 million, plus approximately the same amount for the following 2 fiscal years, should enable us to award a minimum of three contracts.

The combustion process itself is another aspect of our program that would receive specific attention in the 1985 budget.

The program has been successful in moving the fluidized bed combustion process into commercial application at moderate industrial scale. Our 1985 budget would continue to improve the competitiveness of this environmentally clean combustion option in the smaller boiler markets where oil and gas now dominate and in the multihundred-megawatt utility market.

We are continuing efforts in the coal preparation program to upgrade U.S. coals to qualities that would allow them to meet environmental standards with no further controls, or to be used in clean coal-based slurries that could compete with conventional liquid fuels.

We are continuing efforts in coal slurry combustion as a way of expanding coal's use in oil- and gas-fired boilers and furnaces, as well as potentially in gas turbines and diesel engines. We are maintaining core research and development in fuel cells, where we believe the phosphoric acid version of this technology is at a point where the private sector can make further investment decisions. We have proposed a new initiative in the MHD program that will enable us, we hope, to move the program toward a logical proof-of-concept test facility.

We are continuing fundamental laboratory and bench scale studies in coal liquefaction and gasification, as well as in oil shale and enhanced oil recovery. And in unconventional gas, we are continuing to conduct research efforts at the multiwell tight sands project in Colorado, as well as establishing a technical data base for eastern shales. We are also continuing to investigate novel sources of gas, such as hydrates and deep-source gas.

In short, Mr. Chairman, the 1985 budget proposal offers us the opportunity to continue advancing the technology of fossil fuels. We believe it is a sound budget and, given the fiscal constraints that continue to confront this Nation, we believe it is a fiscally responsible budget.

With that, I will be pleased, Mr. Chairman, to answer your questions and those of your colleagues.

[The prepared statement of Mr. Vaughan follows:]

# STATEMENT OF WILLIAM A. VAUGHAN
ASSISTANT SECRETARY FOR FOSSIL ENERGY
U.S. DEPARTMENT OF ENERGY
BEFORE THE
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
MARCH 7, 1984

Mr. Chairman and Members of the Committee:

The Fiscal Year 1985 budget request for the Fossil Energy Program reflects the Department's commitment toward establishing a stable and productive funding profile for coal, petroleum, oil shale, and unconventional natural gas research and development efforts.

The $274.87 million[1/] requested for these activities has been fashioned on three basic principles:

1) Consistency with the National Energy Policy Plan

The budget request is consistent with the primary goal of the 1983 National Energy Policy Plan to "foster an adequate supply of energy at reasonable costs" and the two strategies adopted by the Administration for achieving it: 1) promote a balanced and mixed energy resource system, and 2) minimize federal control and involvement while maintaining public health and safety and environmental quality.

Issued in October 1983, the fourth National Energy Policy Plan was developed at a time when the U.S. energy situation had significantly improved from the price surges and supply shortages that characterized the decade of the 1970s. Total energy efficiency has increased, oil prices have declined, and U.S. vulnerability to disruptions in foreign energy supplies has been reduced markedly.

Yet one fundamental aspect of today's energy situation still closely parallels that of prior years. Fossil fuels -- oil, natural gas, and coal -- continue to account for 90 percent of the energy consumed in the U.S., and the 1983 National Energy Policy Plan doesn't depart substantially from its 1981 predecessor in projecting that as much as 70 percent of our energy will continue to come from fossil fuels well into the next century.

If this future energy pattern is to be achieved without compromising the nation's environmental and economic objectives, the private sector will continue to require a sound base of scientific and engineering information on improved fossil energy concepts. The funding requested for the FY 1985 Fossil Energy program will continue to build this knowledge base.

The FY 1985 budget request follows the two basic strategies for achieving the Administration's energy goal defined in the National Energy Policy Plan:

- to promote a balanced and mixed energy resource system.

During every year of the past three decades, conventional sources of oil and natural gas have accounted for at least 60 percent -- and in some years more than

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[1/] Funding is for research & development programs and Liquefied Gaseous Fuels Spill Test Facility only. Funding request for Strategic Petroleum Reserve and Naval Petroleum and Oil Shale Reserves is described in separate testimony.

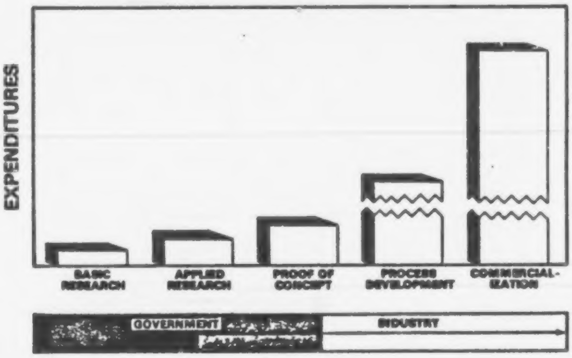
75 percent -- of the primary energy consumed in the U.S. Coal, on the other hand, is currently supplying less than 25 percent of the nation's energy needs. The National Energy Policy Plan's strategy of promoting a more balanced and mixed energy resource system is implemented within the Fossil Energy program by placing a high priority on increasing the competitiveness of coal in markets currently dominated by oil and gas. To achieve this, R&D efforts are focused on improved technologies for direct coal combustion and combustion of coal mixtures and the conversion of coal into liquid and gaseous fuels and feedstocks.

The FY 1985 Fossil Energy program will also emphasize advanced technologies for recovering additional fuels from the large domestic unconventional gas resource and from the currently unrecoverable portion of the petroleum, oil shale and tar sand resources.

- to minimize federal control and involvement in energy markets while maintaining public health and safety and environmental quality;

In this regard, the FY 1985 Fossil Energy budget request continues to emphasize generic or cross-cutting research that is unlikely to result in company-specific proprietary knowledge. It continues to focus the Federal role on the early stages of research and development, i.e., basic and applied research through the technical proof-of-concept (as shown in the following diagram)[2] which are not likely to attract substantial private sector support without federal involvement:

**TECHNOLOGY DEVELOPMENT PATH**



In addition, the FY 1985 budget request reflects an emphasis on maintaining public health and safety and environmental quality by proposing continued funding for health and environmental studies related to emerging fossil fuel processes, such as coal gasification and liquefaction and oil shale retorting, and by initiating new research efforts directed specifically toward innovative technological options designed to reduce power plant emissions that may be associated with acid rain.

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[2] The stages of the Technology Development Path are defined at the conclusion of this testimony.

## 2) Continued Emphasis on Federal Spending Controls

The request continues to emphasize the President's commitment to controlling Federal spending as an integral component of the nation's ongoing economic recovery.

The economy is moving into 1984 with a strong momentum that all but ensures a sustained period of real economic growth with an inflation rate roughly half that of three years ago. Yet, federal borrowing continues to subject credit markets to increasing pressures. Throughout the Department, emphasis continues to be maintained on keeping budgets at the minimum levels required to ensure the continuation of viable, productive core R&D programs.

Within the Fossil Energy portion of the budget, substantial emphasis has been placed on private cost-sharing both to facilitate the transfer of technology to the private sector and to reduce federal expenditures. Inherent in the budget request is an attempt to attract research performers which have a long-term institutional commitment to an area of research and to the ultimate application of research results. For example, the FY 1985 request proposes a significant program to construct an integrated, coal-fired magnetohydrodynamic combined cycle system that is contingent upon adequate cost-sharing by the private sector.

## 3) Accomodation of Congressional Intent

The FY 1985 Fossil Energy budget reflects a genuine attempt to accommodate the intent of Congress regarding the pace of the Fossil Energy program.

As Energy Secretary Don Hodel has stressed in prior budget-related statements, a research and development program, particularly one that emphasizes the early stages of fundamental science and engineering, cannot achieve maximum productivity over the long-term with fluctuating budget levels. In the past, the amount of funds requested by the Administration for Fossil Energy R&D and the final appropriations approved by Congress have differed by as much as a factor of three. The FY 1985 budget attempts to eliminate the "stops-and-starts" that often disrupt multi-year research projects when funding differences of such magnitude exist.

The FY 1985 funding request of $274.87 million[3/] represents a significant increase over the FY 1984 request of $138 million. Although the request is below the level of Congressional appropriations for the FY 1984 Fossil Energy program ($329 million), partly due to the completion of several large pilot plants and process development unit projects, it represents a significant effort by the Administration to reach an accomodation with Congress on the content and level of a technically-defensible Fossil Energy R&D program while meeting the strategies of the National Energy Policy Plan and continuing the Administration's emphasis on federal spending controls.

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[3/] Includes $2.0 million for Liquefied Gaseous Fuels Spill Test Facility.

## THE FY 1985 FOSSIL ENERGY BUDGET REQUEST

The proposed FY 1985 Fossil Energy budget of $274,870,000 would be comprised of five major components, grouped into two categories:

| | FY85 Budget Authority |
|---|---|
| Coal ...................... | $ 177.99 million |
| Petroleum ................. | 31.60 million |
| Gas ....................... | 8.55 million |
| Policy & Management ....... | 54.73 million |
| Research & Development... | $ 272.87 million |
| Liquefied Gaseous Fuels Spill Test Facility ................ | $ 2.00 million |
| FOSSIL ENERGY TOTAL...... | $ 274.87 million |

The $274,870,000 million is derived from five categories of funds:

| | |
|---|---|
| -- New Budget Authority .................... | $ 204.73 million |
| -- Unobligated Fossil Energy R&D and Construction Funds from Prior Years ........................... | 58.84 million |
| -- Unobligated Alternative Fuels Production Funds from Prior Years ...... | 5.80 million |
| -- Unobligated Energy Production, Demonstration, and Distribution Funds from Prior Years ................. | 2.50 million |
| -- Transfer of Funds from Loan Guarantee Fees collected under P.L. 96-126 ....... | 3.00 million |
| Total ......... | $ 274.87 million |

The unobligated prior year balances from the Fossil Energy R&D and Construction accounts is made up of unspent funds from the terminated high and low/medium Btu gasification demonstration plant projects, the Solvent-Refined-Coal I and II demonstration projects, the geopressured methane program, and pre-1984 funds from the surface coal gasification, coal liquefaction, and program management accounts. Also included in this amount are $6 million of FY 1984 funds that are expected to be derived from implementing new management improvement initiatives.

The unobligated Alternative Fuels Production funds represent funds remaining in the budget account established under P.L. 96-126 to finance feasibility studies and cooperative agreements for synthetic fuel and certain other alternative energy facilities.

The Energy Production, Demonstration, and Distribution funds remain unspent from the Coal Loan Guarantee program established in 1976 to encourage small operators to open low-sulfur coal mines or build preparation plants. There have been no qualified applicants for this program; therefore, the remaining funds are proposed for use in offsetting a portion of the FY 1985 budget.

A portion of the Loan Guarantee Fees paid by the Great Plains Gasification Associates to the Federal Government for guarantees of obligations issued from the Federal Financing Bank would also be transferred to the Fossil Energy budget to carry out the Department's monitoring provisions of the Loan Guarantee Agreement (see p. 12).

In addition, the FY 1985 budget request includes $15 million appropriated by the Congress during the last fiscal year for federal support of the atmospheric fluidized bed demonstration facility under the administrative and technical direction of the Tennessee Valley Authority. Under provisions of the FY 1984 appropriation language, the funds are to be made available on October 1, 1984, and an additional $15 million is to be made avaiable on October 1, 1985.

The major budget categories within the FY 1985 Fossil Energy request are described in the following pages.

## COAL

### CONTROL TECHNOLOGY AND COAL PREPARATION

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 27.9 | $ 26.0 | $ 32.2 |

The Control Technology and Coal Preparation program takes on added relevance in FY 1985 in light of the National Energy Policy Plan's objectives of fostering a more balanced energy resource system while maintaining necessary environmental quality.

The potential of coal is hindered, in large measure, by its inherent environmental disadvantages. Furthermore, sulfur and other mineral constituents in even the nation's best coals impose cost penalities on all phases of the fuel chain -- in transportation, boiler design and operation, gas cleanup, and waste disposal. The goals of the Control Technology and Coal Preparation activity, therefore, are to develop the technology base to:

| | |
|---|---|
| o Upgrade U.S. coals to qualities that allow them to meet environmental standards with no further controls, or to be converted into clean coal-based slurries that could compete with conventional liquid fuels (Coal Preparation)................. | $ 11.15 million |
| o Improve the capability of removing pollutants from the flue gas of coal combustors (Flue Gas Cleanup)............................................ | $ 14.03 million |
| o Remove undesirable substances produced during gasification and/or combustion, thus protecting downstream equipment such as turbines and fuel cells (Gas Stream Cleanup)........................... | $ 4.98 million |
| o Provide waste disposal technologies that will comply with environmental regulations without excessive costs (Waste Management)..................... | $ 2.00 million |

Also in FY 1985, the Control Technology and Coal Preparation program will contain significant new initiatives to develop technologies with specific potential for controlling the release of pollutants thought to be contributors to the problems of acid rain (called "acid rain precursors"). Research efforts will focus on:

- Developing the capability to reduce the emissions of suspected acid rain precursors from existing coal-fired boilers.

This new effort is being carried out within (1) the Coal Preparation program where testing will begin in FY 1985 to determine if advanced physical coal cleaning technologies have the potential for use as acid rain precursor control options, (2) within the Flue Gas Cleanup program where a competitive procurement will be issued to evaluate acid rain precursor control technology at the proof-of-concept scale, and (3) within the Gas Stream Cleanup program where various process modifications might be made to prevent acid rain precursor formation.

## COMBUSTION SYSTEMS

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 24.2 | $ 18.2 | $ 31.7 |

Like the Coal Preparation and Control Technology program, the Fossil Energy Combustion program is closely coupled to the environmental and balanced energy supply objectives of the National Energy Policy Plan. In prior years, the technological information emerging from this program has led to the commercial introduction of a new combustion option for the nation's industrial sector -- the atmospheric fluidized bed combustor. This technology, now offered within the product line of nearly every boiler manufacturer, offers the environmental advantages of capturing sulfur dioxide and reducing nitrogen oxide formation within the boiler, eliminating the need for expensive scrubbers. More recently, the program has extended its research efforts into technologies with even greater potential including those that would allow coal to compete directly with oil and gas in existing as well as new boilers.

In FY 1985, the Combustion Systems program will focus on activities to establish the technology base for:

| | |
|---|---|
| o Expanding the application of atmospheric fluidized bed (AFB) combustion concepts (1) into the smaller industrial boiler market through lower cost technology, (2) into the combustion of low-rank coals, and (3) into the utility market; (Atmospheric Fluidized Bed Combustion) | $ 17.5 million |
| o Continuing development of the pressurized fluidized bed concept, including continued research at test rigs at New York State University and the General Electric Long Term Materials Test Facility; (Pressurized Fluidized Bed Combustion) | $ 5.0 million |
| o Investigating combustion phenomena and other characteristics of coal-based slurries such as coal-water and coal-water-alcohol fuels; (Alternative Fuels) | $ 7.2 million |
| o Developing the means for coal and coal-based mixtures to be fired directly in existing oil/gas designed boilers and process heaters with minimal derating via a precombustion de-ashing step; (Advanced Combustion Technology) | $ 2.0 million |

The major increase in the FY 1985 funding level for the Combustion Systems program compared to FY 1984 is due to the inclusion of $15 million in the Atmospheric Fluidized Bed Combustion activity to support the 160-megawatt EPRI/TVA Utility Demonstration Plant at Paducah, Kentucky. The funding was appropriated in FY 1984 to become available in FY 1985. An additional $15 million would also be made available in FY 1986.

Also within the Atmospheric Fluidized Bed Combustion program, FY 1985 funds would continue the benchscale testing of the most promising of innovative fluidized bed concepts that could be particularly applicable for smaller (less than 150,000 pounds of steam/hr) applications where oil and gas are now more economical.

Funds have also been requested to support the Pressurized Fluidized Bed (PFB) Combustion program including the PFB test rigs at New York University and the General Electric Long Term Materials Test Facility as well as to support research and data analysis. In addition, funds have been requested in FY 1985 to permit the Department to share the costs of utilizing the PFB combined cycle pilot plant in Wood-Ridge, NJ, if partners can be found in FY 1984 who are willing to participate financially. The Curtiss-Wright Corp., which constructed the pilot facility under a cooperative agreement with DOE, was unsuccessful in securing private sector funding to operate the plant. In the event that the Department is unsuccessful in obtaining cost-sharing partners, the facility would be placed in standby until future needs are determined. In this event, the requested funds would be applied to an ongoing effort to better define the overall R&D needs of PFB technology and to enhance the compilation of a sound technological data base on the PFB concept.

FY 1985 funds for the Alternative Fuels program would complete efforts in coal-water mixture technology research for utility and large industrial applications. Efforts will then be focused on other coal-liquid mixture technologies, such as micronized coal-water slurries mixed with volatile organic compounds.

The funds requested for the FY 1985 Advanced Combustion Technology program would extend the work begun in FY 1984 to develop the means for retrofitting coal-fired combustors onto existing oil- and gas-fired boilers. Research in FY 1985 will focus on the capability of these combustors to prevent molten ash particles, called "slag", from being transported into the boiler (accounting for the name "slag rejecting" combustors), on reducing sulfur dioxide and nitrogen oxide emissions, and on increasing the capability to burn a variety of coals. The FY 1985 program should establish the economic competitiveness of these retrofit combustors for utility and large industrial boilers. Additionally, funds are requested to advance through benchscale testing the most promising of several innovative concepts potentially applicable to smaller boilers.

HEAT ENGINES

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 5.1 | $ 6.5 | $ 7.7 |

While the Combustion Systems Program is focusing on the use of coal and coal slurries in boilers and process heaters, the Heat Engines program is directed towards the longer-term goal of utilizing advanced coal slurries or gaseous fuels in gas turbine and diesel power systems currently powered with distillate fuels or natural gas.

The ultimate goal is to develop a technology base to permit the private sector to assess the commercial viability of coal-fueled power conversion systems. The DOE program's principal purpose, therefore, is to:

| | |
|---|---|
| o Establish basic component cooling, component materials, combustion, and coal-slurry quality data necessary for firing coal slurries in gas turbine power conversion systems ........................ | $ 4.4 million |
| o Establish basic design, combustion, materials, and fuel interaction and related data for coal slurry firing in diesel power generating systems......... | $ 1.7 million |
| o Continue laboratory research to interpret engineering test data and resolve fuel and design uncertainties........................................ | $ 1.6 million |

In both the turbine and diesel areas, FY 1985 funds would be used to select reference fuel specifications that are needed to make engineering evaluations of critical component or engine designs. Preliminary testing would also begin on selected turbine components and diesel engines designs.

## COAL LIQUEFACTION

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 37.6 | $ 28.9 | $ 13.9 |

Although current projections (including those of the National Energy Policy Plan) do not point to large price increases in the relatively near future, in the long term, particularly as we move into the next century, the lowest cost energy supply as well as our national economic and security interests may dictate that synthetic fuels, including liquids made from coal, be substituted increasingly for conventional oil and natural gas.

To establish a sound, long term and effective synthetic fuels capability, industry will need to develop lower cost, more efficient liquefaction technologies which can utilize the U.S. coal resource base. The FY 1985 Coal Liquefaction Program, therefore, would continue to:

- Provide data on improved indirect liquefaction technology that can utilize synthesis gas produced by modern gasifiers with a minimum of downstream processing; (Indirect Liquefaction).............$ 2.5 million
- Aid the development of more advanced direct liquefaction processes that could produce 10 to 15 percent higher, improved quality yields than earlier methods with cost improvements approaching 30 percent; (Advanced Process Development)...........................$ 5.6 million
- Provide engineering analyses, data base management, and investigation of key instrumentation/component requirements (Support Studies/Engineering Evaluations)................$ 5.8 million

It is generally agreed that any significant use of coal liquefaction will probably not occur before the turn of the century. Therefore, the FY 1985 budget request continues to be refocused on longer-range, laboratory scale projects that could lead to a new generation of liquefaction technologies. Also, both the Methanol-to-Gasoline project (Federal Republic of Germany) and the Liquid Phase Methanol Synthesis project (LaPorte, Texas) are now operating and expected to continue test runs through at least part of FY 1985. Funds are sufficient from prior years to carry out the currently planned test operations at these two indirect liquefaction facilities.

In FY 1985, indirect liquefaction research will continue at laboratory scale and with private sector participation to develop new and improved catalytic synthesis technology.

In the direct liquefaction area (termed "Advanced Process Development"), DOE-sponsored research at the EPRI/Southern Company-owned advanced concepts liquefaction test facility at Wilsonville, Ala., will be concluded by December 1984, and no additional funds are requested in FY 1985. Benchscale activities will also have been concluded in 1984 on new methods for direct catalytic liquefaction and innovative concepts involving slurry oil composition and preheater/prereactor performance.

Technology base activities will continue in FY 1985 in catalyst research for direct liquefaction, including slurry phase catalysts for liquefying low rank coals. Laboratory scale investigations will also be conducted on new direct liquefaction process concepts that could offer further reductions in capital costs and improved process operability. Most of this work will be conducted in-house, along with one industrial contract scheduled to be awarded by competitive solicitation in FY 1984.

Funding has been added in the Liquefaction Budget in FY 1985 for data base management to ensure that information from previous projects and modeling studies is captured and made useful and available to industry. Also within the Support Studies activity, additional efforts will be conducted in FY 1985 to characterize the biochemical nature of products from advanced liquefaction concepts, such as two stage liquefaction. Chemical upgrading studies will also be undertaken.

## SURFACE COAL GASIFICATION

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 38.8 | $ 36.8 | $ 15.0 |

Coal gasification has become the first of the coal-based synthetic fuel options to reach modern-day commercial application. Through gasification, coal can be used for manufacturing low/medium Btu fuel gases for industrial and electric utility uses as well as synthesis gas as feedstocks for chemicals or liquid fuels or for upgrading into high-Btu pipeline quality synthetic natural gas. Industry has taken significant strides within the last year to advance commercial gasification technology. In addition to several smaller, on-site gasifiers, four large commercial-scale gasifier concepts are now operating or are in the final stages of construction in the U.S.:

- Fourteen 1000-ton per day Lurgi fixed-bed gasifiers at the Great Plains Coal Gasification Plant under construction in North Dakota (12 of which will operate during full production with two kept on standby);
- Four 900-1000 ton per day Texaco entrained bed gasifiers, two of which are now in operation at the Tennessee Eastman coal-to-methanol facility in Kingsport, Tenn., and two which are being installed at the Cool Water gasification/combined cycle plant under construction at Daggett, Calif.;
- A 600-ton per day KilnGas horizontal rotating gasifier now in startup at the Wood-River Power Station near Alton, Illinois; and
- An 800-ton per day Dowsyn entrained bed gasifier now in operation at Dow Chemical Company's demonstration unit in Louisiana.

With commercial experience now being generated in the U.S. from operating or soon-to-be-operating full-size gasifiers, the Department's FY 1985 Surface Coal Gasification budget request is again emphasizing more generic studies to improve the fundamental understanding of gasification principals and the total gasifier system. In carrying out this program, the FY 1985 budget request would:

- o Establish a comprehensive technology data base for new gasifier concepts and gasification systems integration, including process fundamentals, new waste water treatment techniques, computer modeling, and basic data on kinetic and fluid dynamics, thermochemistry and process chemistries; (Advanced Process Development).....................................$ 4.45 million
- o Continue development at small scales of hybrid gasifiers, determine methods to optimize the gasification system and associated process units, and develop the engineering data needed to increase the gasification facility's efficiency and reliability by improving components, instrumentation and control techniques, and applying new material technologies; (Systems Engineering Concepts).............................................$ 3.98 million
- o Produce technical and environmental assessments and engineering evaluations associated with gasifier concepts and systems; (Environmental and Engineering Analyses)................................$ 3.56 million

While large scale gasification pilot plants and process development units that have been funded in the past will be completed prior to FY 1985, the core gasification program will maintain a significant effort to build upon and improve the data base now being developed in the U.S.

Within the Advanced Process Development budget request, a large number of tests will continue to be run at the Advanced Gasification Test Facility located at the Morgantown (WV) Energy Technology Center. This facility, which houses small, laboratory-scale fluid and entrained bed gasifiers, provides a highly flexible test bed for studying the gasification process as operating conditions are varied. This data will be used to confirm the kinetic and thermodynamic assumptions used in several modeling codes being considered for use in the gasification technology data base.

A study of "hybrid" reactors which would link gasification and combustion processes would begin in FY 1985 under the proposed funding request for Systems Engineering Concepts. This concept would incorporate within the gasifier the capability to process feedstocks such as beneficiated coals and/or gasify coal in a manner particularly suited to produce the optimum product (liquids, chars, and gases) tailored to a more sophisticated marketplace.

Within the Environmental and Engineering Analyses budget request, studies will continue on gasification plant environments, fugitive emissions, and effects on workers of accidental exposures to plant waste streams. Also in FY 1985, work will continue to upgrade the ASPEN computer model which has the potential of becoming an extremely effective tool for storing, evaluating, and using a wide spectrum of gasification technology data.

In early FY1985 (December 1984), the Great Plains Coal Gasification plant is scheduled to begin full production of 125 million cubic feet per day of synthetic pipeline quality gas. The start-up and operation of this $2.1 billion pioneer facility will represent a significant step forward in developing a synthetic fuels capability that would be available should future market forces dicate an expansion of the nation's synfuels industry. The Energy Department remains the responsible agency for:

- o Managing the Federal loan guarantee and monitoring of the project (Great Plains Coal Gasification Project)..........................$ 3.0 million

The Great Plains plant, in addition to being a "first-of-a-kind" commercial venture, also offers significant opportunities for selected research and development activities. In addition to the loan guarantee management and monitoring funds identified above, the Department also proposes to use FY 1985 funds from its Surface Coal Gasification program to (1) initiate slip stream testing at the Great Plains plant to study the performance of instruments, operating components, and construction materials (using funds from the Systems Engineering Concepts account); and 2) apply the commercial operating data that will become available as the Great Plains project starts up to upgrade the ASPEN computer model (using funds from the Environmental Studies and Engineering Analyses account).

UNDERGROUND COAL GASIFICATION

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 6.00 | $ 6.00 | $ 5.85 |

More than a dozen field tests to determine if subbituminous coal seams could be gasified underground have produced an extensive data base which should allow industrial groups to design the next logical step -- tests to validate the concept in 10-40 ft. thick flat-lying subbituminous coal seams. Accordingly the Federal government's program has been redirected to develop gasification concepts more applicable to less favorable coal resources such as higher ash or swelling coals. To carry out this program, FY 1985 funds are requested to:

- o Investigate environmentally acceptable in situ technologies for converting less desirable coals, such as high-ash subbituminous coals and high-sulfur bituminous coals, into synthetic gas suitable for direct use or for conversion to higher quality products (Gasification Technology Development)................$ 3.15 million

- o Ensure that the necessary post-burn environmental monitoring of past sites is conducted according to state requirements and that long-term research is continued in the cleanup of contaminants left following underground gasification (Environmental and Advanced Research)................$ 2.70 million

A significant addition to the underground gasification data base was made last year when a partial seam test of the novel Controlled Retracting Injection Point ignition technique was completed in a subbituminous coal bed in the State of Washington. Assuming favorable preliminary post-burn analysis of this initial field test, funds from the FY 1985 budget would be used to conduct a logical follow-up test that would encompass greater coal thickness, techniques to increase burn width, and other improvements. The costs of such a test would be shared by industry.

In addition, efforts will continue in FY 1985 to broaden the underground coal gasification data base to include high-sulfur bituminous coal. Characterization of a selected coal site will be completed in FY 1985 along with the design of outcrop tests that would give the necessary information to design the first underground test.

The existence of old underground gasification test sites, principally in Wyoming, afford a unique opportunity to study the effectiveness of physical, chemical and microbiological cleanup of contaminants left following gasification. The FY 1985 budget would provide funds for the Western Research Institute (formerly the Laramie Energy Technology Center) to continue this long-term research.

## FUEL CELLS

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 29.9 | $ 42.6 | $ 13.7 |

Funds for the FY 1985 Fuel Cell program are being requested to continue the technology base program. The 40-kilowatt field test project and the 4.8-megawatt demonstration project in New York City are fully funded and are not anticipated to require FY 1985 funds. The phosphoric acid fuel cell development activities have progressed to the point where the private sector can assume a greater financial role in moving the technology into commercial application.

As a result, the Federal funding request is being reduced in the phosphoric acid fuel cell program. Funding would also be reduced in the molten carbonate development program due to reduced emphasis on the test verification of individual fuel cell stacks. This is a result of continuing difficulties in cell designs and materials and the requirement to resolve these more fundamental problems before proceding to multiple stack fabrication and verification. The Department will also attempt to acquire additional private sector cost sharing for molten carbonate technology development.

A portion of the reduction in funding from FY 1984 to FY 1985 is also due to the recent transfer of the Thermionics program, which had been funded under the Advanced Concepts portion of the fuel cell program. This activity will now be conducted by the Department's Office of Nuclear Energy.

The fuel cell program incorporates significant private sector involvement focused on commercialization, engineering activities, and a portion of the technology base development. Government support is focused on the higher risk cell and stack technology development. In FY 1985, the Fuel Cell program proposes to address:

- Continued development of the phosphoric acid technology for electric utilities and for on site applications (Phosphoric Acid Systems)........................................$ 7.20 million
- Continued development of molten carbonate power plant system technology for both utility and industrial cogeneration applications (Molten Carbonate Systems)................$ 4.10 million
- Continued development of the solid oxide fuel cell (Advanced Concepts)..........................$ 2.40 million

The technical feasibility of phosphoric acid fuel cells has been demonstrated by the operation of several preprototype systems and benchscale tests of new cell designs. In 1983, a U.S.-built experimental utility-sized, phosphoric acid fuel cell went into service in Japan and a 4.8-megawatt unit based on an earlier design is expected to start up in the U.S. in 1984. The first 40-kilowatt onsite fuel cells are now being installed at commercial sites across the country.

With this activity underway, the FY 1985 funding request would be targeted toward a more advanced, potentially more economical phosphoric acid concept that would employ larger area cells. Funds would also be provided to continue work on an air-cooled phosphoric acid concept suitable for electric utility applications and to continue technology development of smaller, on-site systems.

FY 1985 funding in the Molten Carbonate program would be directed at fabricating and testing the first full area, 20-cell short stack and verifying the suitability of cathode materials. Also in FY 1985, the concept of reforming fuel internally in the fuel cell should be verified and data will be available to decide the merits of proceeding with stack development.

The solid oxide fuel cell concept will also be tested in FY 1985 to determine if a 5-kilowatt preprototype module can operate as predicted using coal gas as a fuel. Technology base efforts on the solid oxide concept will also be continued within the requested FY 1985 funding levels

## MAGNETOHYDRODYNAMICS

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 29.0 | $ 30.0 | $ 17.8 |

The FY 1985 budget request includes a proposed realignment in the Magnetohydrodynamics (MHD) Program. A key feature of the new initiative is a requirement for significant cost-sharing by the private sector that should facilitate the proof of concept of MHD technology and provide a clear indication of the private sector's view of MHD's future commercial potential.

The proposed FY 1985 MHD program would be comprised of two elements:

| | |
|---|---|
| o a scientific research program focused on resolving key technical issues; (Scientific Research) | $ 10.8 million |
| o an engineering effort initiating the design, construction and operation of a cost-shared MHD combined cycle proof of concept system; (Integrated Test Facility) | $ 7.0 million |

The MHD scientific program will focus on the fundamental technical problems that must be resolved in order to establish the required technology base for the second phase of the proposed program. For example, information will be developed on (1) the recovery and regeneration of potassium seed material required to render the hot coal gases electrically conductive; (2) on major subsystems such as coal combustors where, for example, erosion and corrosion rates need to be quantified and hardware developed to ensure continuous slag rejection; and (3) on the design and operating conditions required to ensure that ash buildup in the bottoming cycle does not hinder effective heat transfer.

Concurrently, the second phase of the proposed MHD program provides a basis for industry participation and cost-sharing (targed on the order of 50 percent) to design, construct and operate a coal-fired MHD combined cycle proof of concept test unit. The proposed plant would integrate each major component of the power system -- combustor, channel, superconducting magnet, inverter, and heat recovery/seed recovery and regeneration system. The test facility would be sized at an approximate scale of 80 megawatts (thermal input), sufficient to give private industry the information it needs to make future commercial development decisions.

A plan describing the proposed program will be sent to the Congress in early 1984.

Should significant industry cost-sharing not be available, the program schedule would be adjusted accordingly. If no cost-sharing is available, the $7 million funding level requested for FY 1985 would be proposed for use in terminating efforts at the Component Development and Integration Facility in Butte, Mont., and at the Coal-Fired Flow Facility in Tullahoma, Tenn.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 31.65 | $ 39.25 | $ 40.27 |

The Administration's commitment to more fundamental science and technology is reflected in the Advanced Research and Technology Development budget, a cross-cutting function that includes activities underlying the entire spectrum of coal-related programs.

This budget item provides a focal point for government involvement in activities directed toward, for example, developing a better understanding of the basic chemical mechanisms of synthetic fuel production, expanding the knowledge base on the properties of fossil fuel liquids, improving the understanding of coal combustion and the behavior of materials, components and instruments, and exploring new materials, catalysts and electrolytes for fuel cell systems.

To carry out these research efforts, funding for the Advanced Research and Technology Development activity is organized to:

| | |
|---|---|
| o Conduct small scale, fundamental studies of phenomena associated with coal science, liquefaction and gasification; (Processes) | $ 10.03 million |
| o Study the fundamental mechanisms involved in the utilization of low rank coals, chars, beneficiated coals, coal-liquid mixtures, fuel cell and coal-based feedstocks; (Direct Utilization) | $ 10.16 million |
| o Develop a generic technology base for materials used in a variety of fossil energy systems and develop a better understanding of the effects on components of solid materials in fossil energy process streams; (Materials and Components) | $ 8.06 million |

- o Conduct environmental related studies, technical and economic analyses, technology base synthesis, instrumentation, control, and diagnostics; (Technology Crosscut)..............................$ 7.53 million

- o Provide competitively-awarded grants to universities for fundamental projects and student/scientist training (University Coal Research).................$ 4.50 million

Within the Processes portion of the FY 1985 Advanced Research and Technology Development program, a new research effort will be initiated to develop biological approaches to coal liquefaction and to apply new and evolving catalyst concepts, such as cluster catalysts, to coal liquefaction.

Scientific investigations of the properties of coal and coal based fuels prior to combustion will continue in the Direct Utilization portion of the budget request. Also included in the category will be continued fundamental investigations of coal combustion typical of advanced fossil energy concepts, of erosion, corrosion, and deposition resulting from the ash and mineral matter found in all coals, and of separation mechanisms that could remove pollutants and other impurities from hot coal gas streams. Generic fuel cell research will continue to be conducted, and funds will continue to be provided for the IEA-sponsored coal science initiative.

Structural ceramics and ceramic composites will be one of the areas of research to be funded in FY 1985 under the Materials and Components portion of the budget, along with specific efforts focused on the way in which refractory linings in gasifiers and boilers deteriorate under typical operating conditions. The development of specialized components for fossil energy systems and research into bulk solids flow and solids transport are also areas of research within this budget category.

The Technology Crosscut funding request will provide for strategic planning efforts that support the development of Fossil Energy R&D priorities, allow a higher level of participation by the Office of Fossil Energy in the Interagency Task Force on Acid Precipitation, and provide funds for two coal research services operated under the auspices of the International Energy Agency.

Approximately 20 new university research programs would be initiated with the funding provided in the University Coal Research program budget for FY 1985. This activity has attained significant stature in the academic community and is building a valuable national resource of new ideas and knowledge related to fossil energy within the nation's university system.

# PETROLEUM

## ENHANCED OIL RECOVERY

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 6.5 | $ 9.2 | $ 13.4 |

The Department's recognition that liquid fuels are a mainstay of our economy is reflected in the increased funding levels requested for Enhanced Oil Recovery. Nearly two barrels of petroleum out of every three discovered -- a total of as much as 312 billion barrels -- may remain unrecoverable given today's oil prices and limitations of current oil production technology. New concepts and processes will have to be developed if the nation expects to produce significant quantities of oil from these currently unrecoverable resources.

The Department has projected that 18 to 54 billion barrels could be added by current enhanced recovery techniques compared to the nation's known reserves of 28 billion barrels. Yet even that amount would still leave 259 billion barrels in the ground. Only with a fundamental understanding of the mechanisms at work in the geochemically and geologically complex underground oil reservoirs can more efficient, higher recovery processes be developed for these currently unrecoverable resources.

While the private sector has undertaken significant efforts to develop and apply various enhanced oil recovery techniques during the past three decades, actual results have been mixed. None of the processes are well understood, and this has restricted enhanced oil recovery production to relatively simple methods. Moreover, the use of simple, low risk, low efficiency enhanced recovery techniques to recover only a marginal fraction of the oil reduces the reservoir saturation and in all likelihood, renders the reservoir unattractive for further recovery efforts even using novel processes.

The focus of the Department's program, therefore, is based on obtaining a clearer understanding of the scientific processes which govern the behavior of a wide array of enhanced recovery technologies. Specifically, the Enhanced Recovery Program in FY 1985 will focus on:

| | |
|---|---|
| o Fundamental research into the behavior of light oil enhanced recovery processes such as micellar-polymer and carbon dioxide flooding; (Light Oil)................................. | $ 9.20 million |
| o Developing a better understanding of heavy oil recovery processes such as steam flooding and in situ combustion; (Heavy Oil)......................................... | $ 3.00 million |
| o Evaluating and developing new concepts for in situ recovery of bitumen from U.S. tar sand deposits (Tar Sands)..................... | $ 1.20 million |

Improved recovery efficiency for light oil could add from 12 to 23 billion barrels to domestic crude oil reserves. The Department's FY 1985 funding request in this area will increase efforts in fundamental research, data base development and dissemination, and analyses of previously completed tests on enhanced recovery processes. It will also permit some post-test analyses of several projects begun in the late 1970s under the Economic Regulatory Administration's incentive program. One of the products of the Light Oil research effort is a detailed reservoir data file containing over 3500 reservoir descriptions. This file will continue to be expanded in FY 1985 to provide information essential to policymakers and petroleum companies in evaluating the potential for enhanced oil recovery.

The nation's heavy oil resources exceed 100 billion barrels, nearly one-third of the total existing U.S. petroleum resources. The Department's FY 1985 funding request for heavy oil research will increase the level of research into the behavior and mechanisms of heavy oil processes. Working in the laboratory, researchers will study the effects of adding selected chemicals to steam to improve recovery efficiency and examine the kinetics of in situ combustion in representative heavy oil reservoirs. The effects of injecting combustion gases created during the steam production process into the reservoir to aid recovery will also be studied. Work will also continue jointly with Venezuela and Mexico to investigate technical problems associated with producing and upgrading low-quality, heavy crude oils.

Although a recent study of U.S. tar sands revealed that the nation has more tar sand resources than previously thought — 54 billion barrels compared to the previously estimated figure of 36 billion barrels — no commercial production project has yet been successful in this country. The U.S. resource base, with few exceptions, is too deep for conventional mining, therefore the Federal research effort will continue to concentrate on various in situ processes. In FY 1985, in situ combustion methods will be studied along with techniques that inject hot fluids into the reservoir. Novel mining concepts will also be examined to determine their potential in recovering a portion of the nation's tar sand resource, and a series of environmental research activities focusing on both air and water quality impacts of tar sand production will be conducted.

The FY 1985 funding request will also enable the U.S. to continue the exchange of technology with Venezuela and Canada, both of whom are pursuing heavy oil and tar sands technology.

## OIL SHALE

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 12.3 | $ 16.2 | $ 12.0 |

With an oil recovery potential that exceeds the reserves of all of the Middle East, U.S. oil shale deposits represent a significant national resource. In 1984, the first modern-day commercial shale oil production plant — the Union Project in Colorado — is expected to begin full-scale operations, and several other projects backed by the U.S. Synthetic Fuels Corporation are expected to move into more advanced stages of design or construction.

The Federal research program has turned its attention in recent years to more fundamental technology research particularly in the areas of shale fracturing, novel concepts, and environmental mitigation. These efforts would continue in FY 1985 under the proposed funding levels with some further changes in the scope of some of the projects. Specifically, the Department's FY 1985 Oil Shale program would continue to:

| | |
|---|---|
| o Develop the technology base needed to support private sector efforts to improve shale oil technology; (Technology Base)...................................... | $ 6.0 million |
| o Obtain environmental data on the impacts of oil shale development and devise methods to mitigate the environmental impacts of emerging technologies; (Environmental Mitigation)............................ | $ 6.0 million |

The planned activities for FY 1985 are generally in accord with a 5-year research and development plan for the chemistry and physics of oil shale retorting that was developed in FY 1983. Ongoing work in the Technology Base activity will continue in FY 1985 to apply sophisticated analytical techniques to measure the chemical makeup of retort gases, thereby providing an indication of retorting conditions (previous analyses had focused only on shale oil production measurements to determine reaction kinetics). Studies of the kinetics of coking and oil degradation near the retorting zone will also be conducted to provide information for computer models currently being developed. In FY 1985, research to develop kinetic expressions will be used to assist in developing a model that could help predict the behavior of the various chemical constituents of oil shale in an indirectly-heated retort.

The oil shale technology research program was extended in FY 1983 and 1984 to encompass the shales found in the eastern U.S., and certain novel techniques, such as fluid bed retorting, were found to increase substantially the yields of liquid product from these lower grade shales. In FY 1985, research to study the environmental emissions from fluidized bed retorting and combustion will be supplemented by kinetic and modeling studies.

Although no large scale experiments are planned, the FY 1985 budget request includes funds to refine the present rock fragmentation models. Several large scale explosive fragmentation tests have been conducted under previous budgets, and a significant quantity of unprocessed data exists. The FY 1985 effort, therefore, will concentrate on evaluating and processing this data into a more useable form.

Oil shale air emissions and water effluents have a chemical and biological nature that may preclude, in some cases, the use of existing environmental control devices. If an oil shale industry is to develop to its full potential in the future, therefore, a better understanding of the chemical constituents of these materials is needed. The FY 1985 proposed program in Environmental Mitigation would continue to provide this important, fundamental data. X-ray methods will be applied to determine the differing chemical structures of sulfur released in retorting gases, and if feasible, similar methods will be applied to analyses for arsenic, selenium, and cadmium. Mass spectrometry will also play a key role in the FY 1985 program to study trace sulfur compounds and the chemical mechanisms by which they are produced. Limestone scrubbing of sulfur dioxide may be one way of controlling air emissions from future eastern shale oil production plants, and the FY 1985 budget proposes to initiate studies of this technique.

Mathematical descriptions of the kinetics of raw shale processing are also important in controlling emissions, and work will begin in FY 1985 to obtain more accurate information in this area, including the extension of studies from carbon dioxide and sulfur dioxide release to the formation of nitrogen oxides and hydrogen. Studies of the chemical makeup of spent shale as it relates to the retorting process are also planned in FY 1985 using both conventional and newly-developed analytical techniques.

Health effects studies are also a major emphasis in the FY 1985 proposed program, and a specific effort will be focused on identifying specific mutagenic compounds in shale oil and determining the manner in which they are produced. Research that will help determine the makeup of retort process water along with environmentally safe ways of disposing of it, including co-disposal with spent shale, will also be funded in FY 1985.

ADVANCED PROCESS TECHNOLOGY

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 5.0 | $ 5.0 | $ 6.2 |

Crosscutting fundamental research for petroleum and gas technology is contained in the Advanced Process Technology activity. This area is divided into two major components with objectives of:

| | |
|---|---|
| o Investigating novel extraction technology, fundamental chemistry, and environmental research; (Advanced Exploratory Research) | $ 4.5 million |
| o Conducting Arctic-related research and maintaining a publicly-acessible data base; (Arctic and Offshore Research) | $ 1.7 million |

Within the Advanced Exploratory Research program, work will be expanded moderately in FY 1985 to study the novel use of micro-organisms to enhance oil recovery with the most promising techniques to be advanced into small scale field testing.

Fundamental petroleum chemistry research will continue, along with continued efforts to characterize hydrocarbon reservoirs and develop advanced instrumentation. Environmental related research will cover all aspects of the liquid fossil fuel cycle, from extraction to processing to utilization, and will include methods for mitigating aquifer damage and ground subsidence. Laboratory research will also investigate techniques for removing unstable and toxic organic substances from fossil liquids and gases. Studies of fuel/engine interactions will continue with results expected to help determine the extent of air pollutants released when various fossil-derived liquids are combusted. In this way, processing techniques for reducing potential pollutants before they reach the engine can be developed.

The Arctic and Offshore Research program began in FY 1983 as an effort to bring together the information being generated by a variety of Federal programs and to determine where gaps existed in the publicly-accessible data base. Within the Department, basic research efforts will be conducted in FY 1985 to add to this data base. In particular, studies will be conducted on the potential effects of extreme Arctic conditions on drilling and production operations. These studies will focus on ice ridges and islands, the effects of permafrost, and the stability of the seafloor in offshore resource areas.

## GAS

### UNCONVENTIONAL GAS RECOVERY

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 13.7 | $ 15.5 | $ 8.6 |

The completion of several reserve estimates, site characterizations, and a number of field experiments, plus the elimination of activities in the geopressured methane program, result in a reduction in proposed funding for the FY 1985 Unconventional Gas Recovery program. Several activities, however, which will assist the private sector in developing cost-effective technologies required to produce gas from the nation's unconventional gas resources, will continue in FY 1985. Major objectives of the program include the development of:

| | |
|---|---|
| o A technical data base for the Devonian shales of the Appalachian, Illinois, and Michigan Basins; (Eastern Gas Shales)................. | $ 1.5 million |
| o A technical data base for the low-permeability gas sandstones in the Piceance (Colorado), Uinta (Utah), Great Plains (Montana, North Dakota) and Greater Green River (Wyoming) Basins; (Western Tight Sands)................................ | $ 4.8 million |
| o Information on novel unconventional gas resources and environmental assessments; (Environmental and Advanced Research)................. | $ 2.3 million |

The funds requested for FY 1985 in the Eastern Gas Shales area will be used principally to support a test in southern Kentucky that will verify certain reservoir properties, such as flow rates, permeabilities, fracture spacings, etc. The funding request would also continue the acquisition of similar data from various locations within the eastern shale region and the integration of this data into a shale data base. Work would also continue in model development and rock mechanics.

As in past years, the Western Tight Gas Sands activity is focusing on the lenticular, or lens-shaped, sandstone reservoirs which are much more difficult to characterize and produce than the so-called blanket sands that have attracted the most private sector interest. Initial fracturing began at the Multiwell Test Facility in Colorado in FY 1984 and will continue in FY 1985. Generic supporting research, including efforts in geology, fracture mechanics, and modeling, along with work in diagnostics would also continue in FY 1985.

Two new potential gas resources -- methane hydrates and deep source gas -- have attracted interest in the last few years, and funds requested within the Environmental and Advanced Research program will continue to evaluate the long term potential of these resources. Except for a methane hydrate core recovered off the coast of Guatemala in 1981 (a portion of which is now being analyzed by DOE), the dimensions and properties of naturally occurring methane hydrate concentrations and the potential and economics of producing them is unknown. Similar uncertainties surround deep source gas which is thought to be produced by abiogenic means and/or possibly through the transport of organic materials beneath the earth by the movement of tectonic plates. The FY 1985 program will continue efforts to resolve some of the existing uncertainties, yet complete and definitive answers are still several years in the future.

The Environmental and Advanced Research program also includes funds for technology base studies of coalbed methane stimulation and modeling and for environmental assessments required for all field experiments.

Congress appropriated funds in FY 1984 to conduct aspects of a geopressured methane research program within the Fossil Energy program. Historically, this program had been managed by the Office of Conservation and Renewable Energy, and a review by the Department has indicated that this activity should continue to be managed by the Conservation program. Therefore, no funds are being requested for it in FY 1985 as part of the Fossil Energy R&D program and the FY 1984 funds appropriated to the Office of Fossil Energy have been proposed for deferral.

## POLICY AND MANAGEMENT

As Congress directed, the FY 1985 budget consolidates funds for salaries, benefits and travel for the Headquarters organization and overhead/indirect field center expenses. It also provides centralized funding of capital equipment and construction needs. This budget item, therefore, contains three major components:

| | |
|---|---|
| o Program Direction funds for Headquarters and Energy Technology Centers/Project Offices (Management Support) | $ 45.2 million |
| o Capital Equipment (Institutional Investment) | $ 4.5 million |
| o General Plant Projects (Construction) | $ 5.0 million |

The Management Support budget request provides for 127 fulltime (equivalent) positions at the Fossil Energy headquarters, and therefore, assumes that Congress will repeal the currently legislative-mandated minimum employment level of 150 fulltime equivalent positions. (In the interim, the Department will comply with the legislative requirements.) The funding request also supports the indirect costs of the Pittsburgh (PA) and Morgantown (WV) Energy Technology Centers and the Project Offices in Bartlesville (OK), Laramie (WY), and Grand Forks (ND). The program direction funds are divided between Headquarters and the field as follows:

| | |
|---|---|
| Headquarters Program Direction.................... | $ 7.9 million |
| ETC Program Direction.............................. | $ 37.3 million |

The Institutional Investment budget request would permit the field centers, including National Laboratories, to upgrade their analytical equipment. A significant portion of these funds will be used to increase the capacity of the data processing center at the Morgantown Energy Technology Center.

The Construction account would provide funds for several general plant projects needed, for example, to meet OSHA health and safety requirements, repair boilers, and other structures, provide equipment storage facilities, and renovate certain facilities to enable more efficient use of existing space. Also included are funds to complete the waste water treatment facility at the Morgantown Energy Technology Center.

## LIQUEFIED GASEOUS FUELS SPILL TEST FACILITY

(Budget Authority in Millions)

| FY 1983 Approp. | FY 1984 Approp. | FY 1985 Request |
|---|---|---|
| $ 3.5 | $ 3.3 | $ 2.0 |

The Liquefied Gaseous Fuels Spill Test Facility is a new addition to the Fossil Energy budget with funds provided in the DOE Biological and Environmental Science program budget prior to FY 1985. This facility, proposed for siting near , will provide safety and environmental control information on such liquefied gases as liquefied natural gas, liquefied petroleum gas, chlorine, and ammonia. Dissemination of this information to industry, regulatory agencies, and the general public, and its subsequent application, is expected to reduce the frequency of accidental spills and to mitigate the consequences of such spills when or if they occur. Three specific objectives make up this program:

- To develop and validate models of LGF release behavior in sufficient depth to provide a firm technical foundation for promulgating regulations and to adequately support the development of release prevention and control techniques;
- To investigate and validate methods for preventing accidental spills;
- To investigate and validate methods for controlling the consequences of accidental spills.

The spill test facility to be constructed in FY 1984 consists of tanks, dewars, foundations, piping, control systems, berms, a spill pond, an access road and utilities. A portion of the instrumentation, data acquisition systems, large storage tanks, and computer accessories have already been purchased by the federal government.

When the test facility becomes operational in FY 1985, it will be capable of producing spill rates of up to 100 cubic meters per minute with quantities of up to 200 cubic meters. As various liquefied gaseous fuels typical of those found in commerce are released, instruments will measure such characteristics as dispersion, rapid phase transition, pool fire and vapor burn phenomena.

FY 1985 funding will be used to complete fabrication and begin checkout tests of the facility. These activities will include the development of approval processes and procedures for environmental documentation of future tests. The funds will also be used to develop the information necessary for obtaining State and other required permits, and for performing safety analyses to assure personnel and equipment safety.

Checkout tests at the facility in FY 1985 will be financed by Federal funds, however, the Department will make the facility available in future years, on a user fee basis, to private firms and other Federal, state and local government agencies to sponsor their own tests.

Although included within the Fossil Energy program, which derives its research and development funding from the Interior and Related Agencies Appropriations, funds for the Liquefied Gaseous Fuels Spill Test Facility are requested to be provided from the Energy and Water Appropriations.

## DEPARTMENT OF ENERGY
## FY 1985 CONGRESSIONAL BUDGET REQUEST
## SUMMARY OF ESTIMATES BY APPROPRIATION BY MAJOR ACTIVITY
## ENERGY SUPPLY RESEARCH AND DEVELOPMENT
(In thousands of dollars)

| | FY 1983 Actual | | FY 1984 Estimate | | FY 1985 Request | |
|---|---|---|---|---|---|---|
| | B/A | B/O | B/A | B/O | B/A | B/O |
| Liquefied Gaseous Fuels Spill Test Facility ................ | 3,500 | 113 | 3,250 | 3,937 | 2,000 | 4,700 |
| Total ...................... | 3,500 | 113 | 3,250 | 3,937 | 2,000 | 4,700 |

## DEPARTMENT OF ENERGY
## FY 1985 CONGRESSIONAL BUDGET REQUEST
## SUMMARY OF ESTIMATES BY APPROPRIATION BY MAJOR ACTIVITY
## FOSSIL ENERGY RESEARCH AND DEVELOPMENT

(In thousands of dollars)

| | FY 1983 Actual | | FY 1984 Estimate | | FY 1985 Request | |
|---|---|---|---|---|---|---|
| | B/A | B/O | B/A | B/O | B/A | B/O |
| COAL: | | | | | | |
| Control Technology and Coal Preparation ................ | 27,900 | 22,399 | 26,000 | 25,597 | 32,150 | 33,957 |
| Advanced Research and Technology Development ..... | 31,650 | 41,640 | 39,250 | 38,643 | 40,267 | 42,531 |
| Coal Liquefaction ............ | 37,600 | 87,514 | 28,900 | 38,309 | 13,900 | 14,682 |
| Combustion Systems ........... | 24,200 | 35,374 | 18,200 | 17,918 | 31,675 | 25,112 |
| Fuel Cells ................... | 29,938 | 25,906 | 42,600 | 41,940 | 13,700 | 14,470 |
| Heat Engines ................. | 5,112 | 9,410 | 6,500 | 6,399 | 7,650 | 8,080 |
| Underground Coal Gasification | 6,000 | 7,333 | 6,000 | 10,381 | 5,850 | 6,179 |
| Magnetohydrodynamics ......... | 29,000 | 32,660 | 30,000 | 29,534 | 17,800 | 18,800 |
| Surface Coal Gasification .... | 38,800 | 52,247 | 36,790 | 36,220 | 15,000 | 15,843 |
| Subtotal Coal ............. | 230,200 | 314,483 | 234,240 | 244,941 | 177,992 | 179,654 |
| PETROLEUM: | | | | | | |
| Advanced Process Technology .. | 5,000 | 4,775 | 5,000 | 4,923 | 6,200 | 6,549 |
| Enhanced Oil Recovery ........ | 6,500 | 7,467 | 9,150 | 9,008 | 13,400 | 14,153 |
| Oil Shale .................... | 12,250 | 10,287 | 16,150 | 15,899 | 12,000 | 12,674 |
| Subtotal Petroleum ........ | 23,750 | 22,529 | 30,300 | 29,830 | 31,600 | 33,376 |
| GAS: | | | | | | |
| Unconventional Gas Recovery .. | 13,680 | 12,923 | 15,500 | 15,260 | 8,550 | 9,030 |
| POLICY AND MANAGEMENT: | | | | | | |
| Policy and Management ........ | 43,300 | 52,966 | 49,540 | 49,969 | 54,728 | 58,414 |
| PRIOR YEAR OFFSETS ............ | -20,136 | ... | -27,326 | ... | -58,839 | ... |
| APPROPRIATION TRANSFERS ........ | -73,700 | ... | -42,040 | ... | -11,300 | ... |
| TOTAL .................... | 217,094 | 402,901 | 260,214 | 340,000 | 202,731 | 280,474 |

# THE TECHNOLOGY DEVELOPMENT PATH

## These Steps Are Defined Briefly as Follows

**Basic Research:**

Studies Directed Towards Development of Fundamental Scientific Knowledge Leading to the Definition of New Energy R&D Concepts;

**Applied Research:**

Activities to Resolve Broad Engineering and Physical Science Problems in Specific Fossil Technologies and Related Areas; However Practical Utility May Not Be Proven At This Stage;

**Proof of Concept:**

Development to Resolve Specific Problems to Determine the Technical and Environmental Feasibility of the Integrated Process. Data is Generated to Evaluate Critical Scale-Up Parameters, Characterize Sub-Systems, Processes, and Products, and to Permit Preliminary Economic Projections to be Made;

**Process Development:**

Increasingly Larger Scale Engineering Design; Construction and Operation of Energy Systems With the Objective of Reducing Technical Risks and Improving the Process Operability, Reliability, Economics, and Environmental Impact;

**Commercialization**

Wide Variety of Efforts to Eliminate Technical, Economic and Institutional Barriers Required for Acceptance of a New Energy Technology into the Marketplace.

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Mr. FUQUA. Thank you very much, Mr. Vaughan. As I mentioned in my opening statement, the budget presented this year certainly is much better as an overall, comprehensive budget than had been submitted in previous years, particularly as it affects fossil fuels. We still have some concerns and differences of opinion about the direction, and I am sure we will get into that as the budget process moves forward. But let me say, it is much better, and the patient is recovering a great deal better than when he was terminally ill a few years ago.

In the last part of your statement, you were talking about the shales in the East and the West. I know there is a considerable difference in the coal. Are the technologies for western shale applicable to eastern shale, or is there any significant difference between the two, as far as getting gas from them?

Mr. VAUGHAN. Let me speak very broadly, and then if you are interested in greater detail, Mr. Chairman, I will call upon one of my colleagues. In general, the western shales tend to have a much higher content of kerogen, and therefore, at least superficially, would appear to be much more amenable to reduction into useful fuel. On the other hand, the eastern shales are much more widespread and in vast quantities. So somewhat like our coal, we simply must look at both; we have them, and we are trying to look at both. I think the technology, it is fair to say, in western shale is more advanced than is the work in eastern shales, but we are continuing work in both.

That disparity is because of this difference in the likelihood of payout for dollars invested.

Mr. FUQUA. So you do not think that there is any significant difference in technology in western shale versus eastern shale?

Mr. VAUGHAN. I think it would just be a matter of refinement in the main.

Mr. FUQUA. Transport would be basically the same?

Mr. VAUGHAN. I believe so, sir.

Mr. BAUER. Mr. Chairman, I think that one could say that with the investment we have made in the technology relative to the Western shale and the lessons that we have learned, one can do an extrapolation and take the maximum benefits of the tools, the processes, the models, and everything we have had and apply that to the Eastern shale program, which will allow us to get a greater return on our dollar and also to pick up time to make maximum use of that resource.

Mr. FUQUA. Mr. Vaughan, several years ago, Congress established some personnel levels within certain parts of the Department of Energy. In fossil energy, you are requesting some levels which are below those floors. If Congress should disallow those reductions, how much money would have to be added to bring those back, or could they be absorbed by programs, and how much are we talking about?

Mr. VAUGHAN. I am going to call on Mr. Walsh to answer that question for you, Mr. Chairman.

Mr. WALSH. We did price out floors prior to submitting this budget, and there is an approximately $3.8 million difference between the program direction request and the floors.

Mr. **Fuqua**. Did you request these levels to OMB and they were reduced there, or were they reduced by the department?

Mr. **Walsh**. We requested them of OMB.

Mr. **Fuqua**. And they were reduced at OMB?

Mr. **Walsh**. And they were accepted by OMB at those levels. What you see in the budget is what we requested of OMB.

Mr. **Fuqua**. So you were the ones who reduced the personnel levels then, not OMB?

Mr. **Walsh**. Yes, sir.[1]

Mr. **Fuqua**. That is one of the first times I have found the culprit.

Mr. Vaughan, you mentioned the MHD program. How does that differ from some of the previous efforts in MHD?

Mr. **Vaughan**. Mr. Chairman, if I can go back in history a little bit, this country in Federal tax dollars has spent over the last 10 years roughly $450 million in the MHD R&D work and about $50 million in the private sector. We have not produced, as a result of that roughly half billion dollar's worth of effort, a system that looks like it is going to close and reach a proof of concept. We have a number of parallel efforts, and we have a number of efforts at various stages in the technological process. What we have proposed in this budget is to take the elements that we have developed thus far and to put them in a system that will cross these parallel lines and, we are hopeful, bring us to a proof of concept as rapidly as possible and make use, to the extent we can, of the investment we have made as a nation over the past 10 years, and involve heavily the private sector with us in this focusing and trying to prove the concept.

We do not have ready for you quite yet the details of that proposal, and we do request your indulgence to come back to this committee, after we have consulted in detail with this industry, which is primarily composed of the potential users as well as the potential manufacturers of the component equipment, as to the details of what a specific program should be. We have our own ideas as to what that should be, but we want that to be a consultative process with the private sector.

We propose to come back to the Congress with the details that we have been able to work out with the private sector by the early part of the summer, in roughly the June or July timeframe. In that sense, I think we have made a significant difference. We want to bring to proof-of-concept, rather than continuing a parallelism which does not look like it will bring us a solution. Also, this is a fundamental change in the administration's part, in the sense that it ends several years of trying to terminate the program in its entirety. We have heard the Congress.

Mr. **Fuqua**. Let me commend you for that. I think that is what our intention was all along. We tried to get it where we could have a proof-of-concept, and let me commend you for finally trying to bring the forces together to come up with an idea. I assume that when those issues are resolved in planning, there will be a timeframe and so forth at that time, and you will keep us informed on what will happen. It is a technology that we have repeatedly supported, and I commend you for trying to bring it to a head and have a proof of concept. Let's find out if it works or not.

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[1] Fossil Energy requested 663 FTE's of OMB which represents a reduction of 52 FTE's from the congressional floor of 715 FTE's. The manpower levels for FE based on OMB's final allowance to DOE was 637 FTE's which appears in our fiscal year 1985 budget request. FE requested a reduction from the floors and based upon OMB's allowance to DOE further reductions were made to FE's requested manpower levels.

Mr. VAUGHAN. We are going to need, Mr. Chairman, the indulgence of some Members of the Congress. In order to do this, we are going to have to use what we have developed to date, and that is going to change a little of the emphasis. We are mindful, however, and it is our expectation that we will use all currently existing elements of the MHD program constructively in this effort. While the emphasis may shift, we do not believe that any particular present locale or site will be thrown totally out of the program. We are working very hard with this concern, again hearing the Congress' concerns.

Mr. FUQUA. You are proposing closing two of the remaining large liquefaction facilities, one in Alabama and one in Texas, as well as reducing a considerable amount of bench scale work and so forth in direct as well as indirect liquefaction. I guess my question is, can we adequately test and be assured that we can go to large-scale facilities without further scale-ups, like at these two facilities that are being closed out?

Mr. VAUGHAN. The simple answer to your question is, yes, we believe we can. But let me ask Mr. Bauer to be a little more specific.

Mr. BAUER. Mr. Chairman, relative to Wilsonville, which is the pilot plant in Alabama where we are doing the work on the integrated two-stage liquefaction, I would like to state at this time that that process is turning out to be highly successful, in terms of the amount of distillate per pound of hydrogen as compared to other processes for which we tested at very large pilot plants scale. So we are starting to see the fruits of our investment. What we wanted to do for liquefaction to enter into the marketplace is to improve the yield and the capital cost and things like that. So if you get more distillate, that is what happens.

What we are doing now is running that pilot plant on Illinois No. 6, and then we will be going on to some other sub-bituminous coal. We will be done with those tests this December of this year. After running two coals—and you have the data from that—you have an analysis of it—it says that you have a good promising process. So what else is on the platter?

We are bringing some other processes along. There is HRI, the direct catalytic process, which will be in the middle of calendar year 1985. So we are bringing processes along, and you constantly see improvements. Trying to increase the number of processes that are on the platter, we do not see any more need for the testing of the integrated two-stage liquefaction process beyond this year. Yes, I know that the private sector is very much interested in further testing of that coal, to test that process on Wyodak and lignite coal. But one would have to test those coals on the very small bench-scale unit before you moved to Wilsonville.

Relative to La Porte, I think shakedown is just about done, and we are ready to start operations, and that runs until March 1985. We are concerned about only a year of operation on that. I did ask an oil company at one time, and they said that the size of that is 35 barrels per day. If you got the good data, the raw data, and the analyzed data, could one scale that up with minimum technological risk, or would you even—this oil plant—go on and make it a pioneer plant or a small plant, whatever the size of the market dictated.

He said, "If you had sufficient heat and material balances and good design data, yes, a year of operation. If you had good data, that is what could be done with it." That process really has potential, that liquid phase you could take that process and apply it. Maybe the utility industry could take that and tie it to an existing gasifier, let's say Texaco, where you have synthesis gas coming out. You could be talking about coproduction from the utility standpoint.

On the basis of the data that we have and our plans for the next year, we believe, Mr. Chairman, that ends our involvement, and that the dollars we are asking for are to continue other good and promising processes. In our coal liquefaction, we think that coprocessing of coal with residue has tremendous potential.

Mr. **Fuqua**. Is it possible to modify this facility so that you could use other coals? One of the problems I think we have had is, most of our work, even the Synfuels Corporation, has been with Western low-sulfur coal. We have an abundant supply of high-sulfur Eastern coal that we should not ignore. My concern is that we have not fully developed these alternative processes such as liquefaction on a lot of that high-sulfur Eastern coal. I was wondering if this could be modified, since the main facility is there, to test some of those where there are similar type processes in the plant.

Mr. **Bauer**. Mr. Chairman, in my discussions with my counterpart at the EPRI, when we modified the—by the way, EPRI owns that facility. Our contract is with Southern Company Services. The decision was made to extend the contract for this year plus an option for next year, and that is the so-called insurance policy to allow decisions to be made in the future relative to that facility.

Mr. **Fuqua**. So this could be a possibility?

Mr. **Bauer**. It could be. No doors are closed. Nothing is foreclosed. The only concern that I have, technologically, is the age of the reactor there at that plant and how much more life is left on it.

Mr. **Fuqua**. If that is possible, it would seem to be a good utilization of a facility that we have and have a considerable amount of investment in to test something that ultimately needs to be tested. I would hope that this possibility would be looked at very seriously.

Mr. **Bauer**. Last year, we did the same, Mr. Chairman, with the aged coal pilot plant and transferred the title to Ashland with the option that they cannot do anything for 3 years without checking with us.

Mr. **Fuqua**. Are they doing that?

Mr. **Bauer**. They have not taken the first piece of equipment out of that. They are maintaining it and complying with the contract. Yes, sir.

Mr. **Fuqua**. I would hope that it is more valuable testing something than using it for scrap iron.

Mr. **Bauer**. They did not scrap it.

Mr. **Fuqua**. It was about to happen last year.

Mr. Vaughan, is there any industrial activity on the pressurized fluidized bed technology? Is the utility industry interested? Are boiler manufacturers or people who use a lot of processed steam?

Mr. VAUGHAN. I can give you a general answer, Mr. Chairman, and then if you care for more specificity, I will call on Don again. We believe that both the atmospheric and pressurized fluidized bed processes have much promise, and we are proceeding with our own involvement with both concepts. I do believe there will be applicability. I do detect—and I am still new enough—and I am still having initial meetings with a number of industry reps. I am most encouraged by the interest in the private sector in what we are doing and the changes that we have made. They are most receptive to the changes in attitude.

I find a great deal of interest in joint venturing with the Government, in working with us in virtually the full range of technologies. I think we are going to see, as a result of this change on our part, a great deal more involvement by the private sector. I can assure you that we have brought to an end any failure to dialog with either the Congress or with the private sector that may or may not have occurred in the last several years. I can assure you that there is going to be plenty of conversation so that there is the most bang for the buck for these public dollars we are spending.

We are very hopeful that we can joint venture with the private sector, so that we can spread the leverage with those Federal dollars. When we do see if a technique or technology we brought to the stage close to commercialization, we would like to phase that Federal involvement out because the Government is not a good commercializer per se. It brings a lot of baggage with it —of necessity, because it uses public funding—and I think that in itself carries a little dampening effect.

We would like to encourage that, but in order to make those judgments—and they are always judgment calls about commercialization and demonstration—we must talk with the people who are going to make and use this equipment. It has to be continuous. It cannot be on and off. That is one of the major things that we already have underway. One of the things I see personally I could do is to make sure that the example is set and that it is real, not just superficial talk, that we are indeed permanently talking with the people who mine and use coal and the equipment that goes with it.

By the way, another theme I think is very important for this country, we ought to tell about the technology we are developing. I am convinced, sir, that in a very short time environmental standards around the world are going to be very close to those in the United States, and we are going to start to realize some benefit from our environmental foresightedness because we will have forced ourselves to develop environmental control equipment. I think we ought to market it, along with the coal, because we have enough coal in this country not only to run ourselves for the foreseeable future but really the rest of the world. We are the Saudi Arabia in coal for the world, even though a lot of it is high sulfur.

We simply must solve the problems, and I am quite encouraged. I think we are solving the problems, and we are going to have to do it jointly with the private sector so that it can be a profitmaker and then a taxpayer and not be a permanent drain on our economy, that is an asset. That will always require some judgments, and I hope that is all we are really talking about in the future, just differences in judgment, fine tuning as I would call it, as opposed to opposing the concepts that you folks or the private sector may have.

Mr. FUQUA. Let me say that I certainly agree with you involving the private sector as much as possible. I grew up on a farm and we raised cattle. I know with calves, you have to provide them nourishment either from their mother or somewhere, until they are able to be weaned. As soon as we can wean this technology, we should. But we cannot put it out in the cruel world too soon or it will starve to death. So there is a fine decisionmaking process of when it is able to be weaned and when it has to have some nourishment. I would hope that we can try to make sure it does not starve in the process.

But I totally agree with you: the Government does a very poor job of commercialization. We can develop it and get it ready to get into the marketplace and then let the market factors take over and develop it. And many times there is high risk associated with it. I was saying awhile ago, utility companies are in bad shape right now because of bonding evaluations. They are very scary, and the people who sell bonds are afraid to death of anything that is new, that may have a tremendous cost overrun or not work.

They know the oil boiler technology and the old coal technology. But when you start talking about new things, then they get a little jumpy about it. I think it behooves the Government to make sure that it is proven and to minimize that risk and uncertainty that may develop in the marketplace.

Mr. VAUGHAN. Your analogy, sir, I think is most apt. To speak very specifically for a moment on the electric utility matter, I am most encouraged in recent discussions, ranging from the MHD proposal on which we have already started some discussions several days ago, the fuel cell interest people.

I agree with you that there are major financial problems for some of this country's utilities. But notwithstanding those problems, I received a very clear signal that they are willing to put up some risk money with us, if they believe we want to accomplish something, now that they think we are no longer fighting the program. So I am most encouraged that we are going to see some dollars.

I would also agree with you on the theme that if it is high risk, that is the sort of thing that is more appropriate for the Federal dollars. I have already tried to encourage our people that we not worry that we crowd the risk side. That means we will find some things that do not become commercially viable. So, be it; that is not wasteful. Any aggressively well run research and development program has lots of failures and many more of those than they do successes. But they really are not failures. Every properly run R&D program has lessons learned, and they are part of the successes. It is just how you get there and making the judgments that you have learned something and that this is not quite the way to go, and now you can try something else.

You have to keep this kind of spirit in this program. I see our job as trying any viable alternative and bring it along, as in your analogy with the calf. We can nurture it to the point where we believe that calf can go on its own, and then make sure that we do step back and let it go on its own, lest it remains dependent because it will not be a very good taxpayer if you do that.

Mr. FUQUA. Thank you for your statement.

DOE has just completed the facility in New Jersey, the pressurized fluidized bed at the Curtiss Wright. What are the plans for that and the cost annually to run that facility?

Mr. VAUGHAN. I will ask Mr. Bauer to give you the specifics in just a moment, but I would like to say something about that facility. I believe we are going to be in the position of deciding about the future of this Curtiss Wright developed facility, and we are going to be in some very delicate negotiations, I believe. I think we have to be very careful to extract from that facility value for the money that we have put on behalf of the public into it. So we will be attempting to do that. Under the contract, I believe Curtiss Wright has served notice on us that they intend to withdraw and turn the facility over to the Government, which they have a right to do.

Mr. FUQUA. Are there any boiler manufacturers——

Mr. VAUGHAN. We are out now, and we have a utility that has already indicated a great deal of interest in the facility and has made an unsolicited proposal to us on the subject. We have that under evaluation. We need to effectively close out the Curtiss Wright contract, if that is the correct terminology. So, as I say, we have something to go forward with, to get them cleanly out of the facility, and then carry on to get the benefit that we intended. We are talking about an operation in the neighborhood of $10 million a year, so this is no minor program as far as I am concerned. It is at a crucial stage at this point, in the sense that we have delicate negotiations to do, not only with Curtiss Wright but also to figure out what we ought to do about this unsolicited proposal or whether we should go even broader with others.

There is interest. Again, some people are saying that it is a failure. I do not agree. I think we have not achieved everything we wanted there, but I do believe there is value. We intend to extract that value from that facility.

Mr. FUQUA. On the subject of fuel cells, you mentioned in your testimony that you particularly believe in the phosphoric acid version of the technology that the private sector can make further investment decisions. Yet I find that there has been a considerable reduction from fiscal year 1984 in the fuel cells program. I guess my question is: Have molten carbonate and the solid oxide programs been tossed out the window, or do they have future possibilities, and do you plan to continue testing those as well as the phosphoric acid process?

Mr. VAUGHAN. The simple answer to your question is that we do intend to continue with the other. Because we are making the judgment, it is again one of these judgments you make that we think the phosphoric acid is at that point, we would expect much less involvement. Although I must tell you that I had meetings just several days ago with people interested in fuel cells. They were saying, "Well, we think you are going a little bit fast there."

The impression I tried to leave with them is, "OK, tell me where I am going too fast? We are not of closed minds on this."

Mr. FUQUA. By "going too fast," you mean in commercialization?

Mr. VAUGHAN. In the closedown of the phosphoric acid and our involvement. They felt that there were yet a few more things that we should do. I said, "That is not cast in concrete. We will look at them. That is not a promise to do it, either. We still may make a judgment call."

I think the reaction there was favorable because we made it very clear that we were not shutting the door. This was a judgment we made, and we had reasons for it, and we discussed it with them in some detail. Then we did ask them, "OK. Tell us then specifically where you think we ought to stay." If we are persuaded that makes sense, even though I have testified to you that the basic judgment is still the same, we would stay involved if there are minor details and it looks like it is appropriate for us to stay in.

Mr. FUQUA. That is primarily on the phosphoric acid?

Mr. VAUGHAN. Yes, sir.

Mr. FUQUA. How far behind do you think the molten carbonate and the solid oxide technology is? You are still planning to keep those two programs going?

Mr. VAUGHAN. The molten carbonate, about 2 years behind it.[2] The other is about twice that long, say on the order of 4.[3] They are hard numbers to be held to, and any number in research and development is difficult, but that is our judgment at this time. We do intend to remain involved with both.

Mr. BAUER. A point of clarification, Mr. Chairman, on that solid oxide the advanced concept. It looked like we were reducing it from 1984 to 1985. In 1984, the appropriations were $4.6 and in 1985 the request was $2.4. One thing that happened was the thermionics program that we had, with the renewed interest in space-power applications, and that program is more closely coupled—we transferred that to the nuclear program, so that is the rationale for that decrease in advanced concepts.

Mr. FUQUA. On the coal-water slurries, you have been testing that for some time. Several companies have announced their intentions to move into the commercial market. The SFC is offering some assistance in the construction of facilities for both industrial as well as utility fuels. My question is: Why do you still need some $7 million that you have in the budget to continue this? Is there still any R&D left? This may be one that is ready to be weaned.

Mr. VAUGHAN. We certainly are at the weaning stage, Mr. Chairman, but there are some things left there that we think ought to be done.

Mr. BAUER. Mr. Chairman, it is safe to say that— I was at a testimony recently down in Blacksburg, where a firm got up and said that they were ready to make coal-water mixture if they could get a guaranteed buyer. A utility got up and said they were ready to burn it if they could get a guaranteed supplier.

Where we are today is that the balance of the work left to do in cold-water mixtures, relative to small-scale utility and industrial applications, as well as cold-water mixtures of cold slurry fuels for heat engine and diesel application, which has application for the utility sector as well as the transportation sector. So it is finishing out the technology for the balance of the market.

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[2] It is more than 5 years behind it.

[3] The other (solid oxide) is on the order of 10 years.

Mr. **Fuqua**. Are there any underground coal gasification processes that could be demonstrated by industry on a commercial scale that are available?

Mr. **Vaughan**. I think that is a little early yet, Mr. Chairman.

Mr. **Fuqua**. What are some of the impediments that you see for that?

Mr. **Vaughan**. The impediments to commercialization I think today are two unresolved issues. I think it has to do with ground water contamination and surface subsidence. I do not think they talk so much about the technological problems, but the environmental problems have to be addressed by both parties before you see that commercialized.[4]

Mr. **Fuqua**. So, primarily, you think it is ground water plus some other environmental factors?

Mr. **Bauer**. Socioeconomic, yes.

Mr. **Fuqua**. Mr. Boucher.

Mr. **Boucher**. Thank you, Mr. Chairman. I want to commend Mr. Vaughan on his statement here today. I am glad to hear his strong support for greater utilization of coal. I, for one, happen to believe that it is the most promising fuel that we have today and that its greater utilization can be the proper path toward achieving American energy independence. I guess I am somewhat concerned, as were the witnesses who testified before the committee yesterday, that we are perhaps not operating a great enough emphasis with regard to research and development funding for coal technologies.

The point was made by the research and development director for one of the large coal corporations in Virginia, who I know you met with yesterday, that the nuclear budget is more than twice that of the fossil fuel budget. At a time when the administration is saying that it promotes balance in energy development and in research and development, how can one justify a nuclear budget that is essentially twice the fossil fuel budget as proposed?

Mr. **Vaughan**. Let me try to answer that question, Congressman Boucher, this way. The whole history of nuclear power is one that really came from the Government. Its entire background, as you well know, started as a weapon potentially. That whole concept of nuclear power, both peaceful and wartime uses, has always been Government, one, historically, but second because there are indeed some necessary regulatory constraints and concerns that one has to have with respect to nuclear power because of the very nature of the energy itself and its ability to do a fair amount of unintended harm. So it is a heavily regulated industry.

It seems to me that it is quite logical and understandable that there has been a tradition and would continue to be a tradition of heavy Government involvement. We continue to have legitimate concerns, like proliferation and the control of proliferation, and that sort of thing. So I think that explains, in a sense, the large Government presence there. I really do not think anybody argues much about it as being a necessary large presence.

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[4] Under certain geologic settings, that is, steeply dipping subbituminous coal beds, underground coal gasification is ready for demonstration at commercial scale. However, it is a little early yet to expect commercialization on a broad scale. The impediments to commercialization are two unresolved issues. There are environmental problems associated with ground water contamination and surface subsidence. The environmental and technological problems have to be addressed by both parties before the technology is commercialized on a broad scale.

Whether it then follows that one should spend an equivalent amount in coal, I do not think that necessarily follows. What one really has to try to do is say, Are we spending an adequate amount? Adequate, of course, is a judgment call. It involves not only are we making progress, are we doing the right things, but also involves what we can afford to do with where we are.

There always will be some disagreements. I talked to the gentleman that you mentioned yesterday. In fact, it was a very interesting conversation, and it was a conversation that I found quite heartening because I found a great deal of effort by that private sector company on its own with its own dollars. By the way, they, as I am sure you are aware, are much interested that we be careful about Government involvement because they want to realize the benefits of their dollars spent, and they want to have a market advantage if they spend their dollars.

Yet, they are, in their research programs, working with us. We have several projects with them. They are interested in that balance. Yes, they make that comparison. My response to a similar question from that gentleman was that I did not really think it would be useful for me to try to set up a competitive, "I should get nuclear dollars," and that sort of thing. I think I should justify dollars that we need for coal on their own merit, rather than saying some of those dollars ought to be shifted over. I told him very candidly I did not think that would be a useful exercise.

Frankly also, the budget process as we build it consists of the program coming forward with what it thinks it can do and should do, and then it gets reviewed at various levels. That is the way we put budgets together in the private sector, and you never get all of that. There rarely is a trading of coal dollars for nuclear dollars or that sort of thing. As you get on up, obviously some things like that have to be done, but it is not done at my level, and it generally is not going to be done too broadly at the Secretary's level either. There is so much investment and history attached and, quite candidly, there is a similar interest in Congress, quite vocal, for nuclear matters. You will end up with that kind of competition.

That is difficult for someone in my position to really be able to tradeoff. I think we are far better building budgets on their technical merits and being persuaded that way, particularly with R&D, rather than trying to trade these other matters off. It is just impossible, it seems to me, and it certainly is for the permanent Federal establishment, the permanent employees dealing with issues of that kind. It is virtually impossible for them to make the right decisions, it seems to me.

Mr. BOUCHER. Thank you for your answer. I do not want to belabor the point, but I think the goal we are all seeking is greater American energy independence. The question is: through which avenues can we best achieve that goal? It seems to me that at a time when we have not had a single new nuclear plant ordered since 1977 and have seen many of the ones that were in the process of construction since that time closing down, that coal provides a far better promise. If one accepts that premise, then I think one questions why the nuclear research budget is essentially twice the coal R&D budget.

I throw it out just as food for thought, and I think your answer adequately states your view concerning it.

Let me ask about a couple of specific aspects of the DOE proposal. We heard yesterday, again from the research and development director at the United Coal Co., that he is very hopeful that a coal-waste recovery project can be instituted with DOE funding, which would result in the production of energy from what is now essentially waste. Have you given any thought to this? I notice there is nothing in the DOE budget this year that addresses that potential.

Mr. VAUGHAN. First I will answer for my own sake and then ask Mr. Bauer to answer in greater detail. I have been interested. As I came into the program shortly over a month ago, I was naturally interested in the environmental problems of things like coal. One of the things that always means is the waste, and that came, if from nowhere else, from my last 3 years of responsibilities and my past associations for some past several decades.

I have already met with ash interests, and I am quite interested that we find useful things to do with the ash that comes from coal. I believe there are useful things we can do. We do not have a program currently in fossil energy budget specifically dealing with that. I certainly intend to throw some ideas at the staff in that regard.

Yesterday, the gentleman from United Coal did mention it, and I told him we would certainly look at it. Yes, we should address waste products, and we certainly should address trying to extract any energy that might exist in those waste products. There, you make a tradeoff. Is it better to extract the energy, or is it better to use it as landfill, a cement—certain types of ash, for example, are fossilonic and make quite good cement.

Mr. BOUCHER. I am glad to hear you suggest that you would view favorably a proposal for waste recovery, for the production of energy from waste. I wonder, in looking at your proposed budget, if there is a category presently in the budget under which you could fund such a proposal. The only category that I see that even comes close would be that of waste management, where you have some $2 million budgeted. But the description of those programs deals solely with data collection with regard to the waste itself and does not refer to energy recovery. Would you need a new category in the budget if you are to fund such a program?

Mr. VAUGHAN. I believe we could include it in waste management, not with those particular dollars since obviously those dollars you see there now are justified in the program. But I think we have some open dollars in the university program. We have virtually doubled that.[5] There are some dollars there with flexibility. Don, are there other categories at this point? Probably not in this budget. But we are already in the process of beginning to put together the next one. To create the category is not difficult. Whether it should be a separate one or not, if the project has merit, I do not think will make much difference. It seems to me, it could easily come under waste management.

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[5] The budget for the university coal research program for the fiscal years 1983, 1984, and proposed for 1985 is as follows: $2.75 million, $4.0 million, and $4.5 million respectively.

Mr. BOUCHER. I was interested in the exchange of questions and answers which you had with the chairman concerning coal slurry fuels. This is a particular interest of mine because we do have, as I indicated earlier, a couple of research projects in my district today that are directed toward having these coal slurry mixtures substitute directly for oil. It is my understanding that a great deal of work does in fact remain to be done, particularly in the development of engines that can accommodate the coal slurry fuel. It is easy enough to mix the coal and water together and to add chemicals which can keep the coal from settling out for the required period of time, and perhaps additional research in that area is not greatly needed.

You were mentioning the diesel engines and the marine engines which, in turn, might burn these coal slurry mixtures. It is my understanding, from talking with people in the industry, that the engines today cannot withstand the additional pressure that is exerted by having coal as the fuel as opposed to diesel oil. Would you care to comment on that? It just seems to me that there is additional research needed in the area of developing the engines, and that well could come under the same category.

Mr. VAUGHAN. The general comments you have made, Mr. Boucher, are technically correct. There is, I want to assure you, a fair amount of interest in engines that can burn this new type of fuel. In fact, historically, Otto Diesel really set out to build a coal-burning engine, and the diesel engine we know today is what finally resulted. The basic theory is still valid. There are problems like wear and some of the compression problems you have mentioned. There is now interest, and the reports I have are that it is an increasing interest as this liquid fuel begins to look like a greater possibility. In fact, we are at the point where in my judgment it is commercial.

Now the idea is to build some engine machinery that can use it, and I think you are going to see that come. I think that there we need to be quite careful, because there is a tremendous private sector, much of it rather well heeled. I left the auto industry, which are major engine builders. There is interest in that quarter, by the way. To that extent, particularly with a former company with which I was involved, I will recuse myself from the detailed negotiations and discussions simply for appearances sake, so there can be no possibility of conflict. But it is reported to me that there is interest and that it is not insubstantial.

So I think you are going to see that thing go. We should be very careful there, I think, about the public funding, not to overdo it because, as I say, these are people who are going to want to make things and then sell them. They are not going to want to have to do it, I do not think, on the basis of—they are going to be concerned about the degree of sharing they have to do. Obviously, when they spend Federal money, they are going to have some obligations about that. So it is a tradeoff on their part, too.

Mr. BOUCHER. We are considering legislation very shortly which may successfully address that problem as well by providing to the recipients of Federal research grants some private patent opportunities.

Mr. VAUGHAN. I commend you for that concern because it is a real one. I think this is a good area in which you will find some concerns there. You will find some companies which, if they think we are close enough, they are not going to want any Federal money. That is one of your tests, by the way, as to how close you are to commercialization: if you have some manufacturers that do not want your money and they are still interested, that pretty well tells you that they do not want the strings that traditionally have gone with it. Let's put it that way.

Mr. BOUCHER. Following up on your answer a few moments ago concerning the present status of coal-water slurry research, you stated that in your opinion the technology is now commercial. I have not seen any commercialization of that technology to date. I am not aware of any. Can you enlighten me on that. Is it being used commercially anywhere today?

Mr. VAUGHAN. Maybe I am a little too enthusiastic there. You cannot go out and buy a load today and actually put it in a piece of equipment. But I think the judgment that I am making technically is that we are virtually there, and I think Don's answer a few moments ago that we have people telling us, "If you will give me a guaranteed buyer, I certainly will make it for you." I think United Coal is a company that is willing to say, "If I can find a customer, I can supply him, and I am ready, willing, and able." You are very close to that commercial threshold at that point.

Mr. BOUCHER. United has not quite gone that far. They are in the process of developing the fuel, but I think they would say—and in fact in their testimony yesterday did say—that additional research is necessary. I am very interested in protecting the recommendation that you have made that additional funding be provided in fisal year 1985 in that category.

Mr. VAUGHAN. One other thing, Congressman. The SFC does have a new solicitation on this subject on the street right now. So it is not just my judgment. Clearly, then, they, too, believe we are very close, if we are not right there.

Mr. BOUCHER. Let me get you to comment, if you would, on the proposals that were made today by Congressmen Rahall and Walgren concerning a 5-year plan for a commitment to research and development for fossil fuels, some $750 million in excess of the regular budgets which DOE will be bringing forward. I personally find that very attractive. I think it would accelerate the conversion by industries and utilities from oil to coal, because we are focusing on those kinds of technologies. I would hope that the department would be supportive of the proposals.

Mr. VAUGHAN. Let me be very candid with you, Congressman. There was much I heard here today from your colleagues that had this legislation. I was hearing their proposals for the first time, although I had glanced through one of the bills last evening. I have discussed the subject and the concept with some of their colleagues over in the Senate, which has some strikingly similar legislation. I think I hear a lot of good things in that legislation. I think as a manager of Federal dollars that have to be spent for R&D, any approaches to trying to get some sort of guaranteed approach so that we know what we are doing 2 years or 3 years—I do not know what the magic number is, but certainly longer term—is a goal that any good manager has to support.

You will have colleagues in the Congress who will not necessarily be totally happy with the approach of out-year funding, but it certainly has advantages for one trying to push technology. We are able to do that, it seems to me, in the defense and space part of the Government involvement, sometimes not with legislation, sometimes with just agreement between the Congress and the administration. It just seems to me that has been a fairly successful effort, and there has been a kind of guaranteed funding that everyone has recognized. That, it seems to me, has a great deal of desirability.

In the sense that this legislation, both bills, as I heard them, encourage private sector involvement, it seems to me that it is highly desirable. It seems to me that is something that is much easier for this administration to look favorably upon, because I think we need private-sector involvement. We need to get some leverage for those dollars. So that part I commend.

I also thought I heard a spirit of not trying to lock in the people responsible for the R&D program to specific projects. I do think that has some negative aspects, and in the sense that I understood those bills correctly, in the sense of allowing decisions to be made about which particular ones and so on would be made in the program rather than in the legislation I think has merit because. I think maybe the first 5-year plan you can write as legislation, but I do not even know that, but after that I think it would be increasingly difficult. It seems to me that the budget process we are in now, where in effect the program brings proposals and is subject to review, it certainly has some merit, too, where the basic decisions are made in the program, although I do believe we need a great deal more, in the theme I mentioned earlier, dialog with the private sector so that we are making the right judgments and they are not simply Federal bureaucratic judgments that are determining the course of our technological future.

I think that spirit, if I understood him correctly, is a favorable one. The specific numbers, I would have to do a lot more study and work on that, and you will have me in real trouble with my colleagues over at the OMB and in the Treasury, so I will pass on that part if I may.

Mr. **Boucher**. I can appreciate that.

Mr. Secretary, thank you very much for being with us. I want to commend you on your presentation here today and wish you well in your work. I, for one, will certainly look forward to working with you. Thank you, Mr. Chairman.

Mr. **Fuqua**. Thank you, Mr. Boucher.

Let me just add a postscript to the recent colloquy between you and Mr. Boucher about the bill. I find also some concern about the specificity of projects that they are talking about. I think we have a better method, probably through the ERAB panel, maybe through the National Academy of Science, EPRI, and some of the other more technical people. One of the problems I find in my experience in the Congress is that we should try to set direction but not try to over-manage a program. That is what you people are hired to do. We can give direction and emphasis, but the level of funding, the type of work, all of these things I think should be left to the technical experts. Many, such as the ERAB panel, the National Academy of Science, and maybe even the National Academy of Engineering and some of the industry groups will make sure that what we are doing can possibly have a commercial application in the future. There is no need to be doing a lot of work on something that has no commercial application, unless there is probably some basic research.

I think we must take a very close look at that so that we do not hamstring the administrators of the program or the Department of Energy in the direction they are going, even though all the programs are probably very worthy and the technologies they are talking about are viable and some that we have supported. I notice one was the MHD; you are trying to move in that direction and maybe some of the others. I do not have the bill before me right at this moment, but I was scanning the bill earlier.

Mr. VAUGHAN. I certainly think that you put your finger on the key concern there, Mr. Chairman. Any time—and certainly there is a history of sometimes not being happy with the judgments that are made, and I understand that scientists and engineers need to have the ability to make as technical decisions, if you are talking about R&D, as they can within some managerial constraints. I do not want to imply at all that I do not think there ought to be some constraints, because there is no R&D program run in the private sector that does not have a lot of management guidance and constraint. You cannot just shovel money at it. But, on the other hand, you really cannot make technological decisions if you are not a technologist. You can only give some guidance, direction, and support and indicate what you want.

It seems to me our process does that fairly well. There is enough money in the future of energy, and coal in particular, and this process brings people up here. Our critics, too. And they should be here if they do not like what we are doing. It does not bend me out of shape at all that we have various groups come up here and very specifically disagree with us. That is what they should do. Out of that process, we get some direction. We should not have that so confrontational that we are throwing bricks at each other, and at times it has gotten like that.

I am concerned in the sense that we, in the legislation, get too specific, particularly if it runs very long. One thing that will cut off dialog faster than anything in the Federal process, I think, is to say, "Oh, Congress said we ought to do it. There it is." What I am concerned about is that there we start running into some problems. There is a great tendency to go ahead and do it, whether it makes sense or not. That we should not do, and I do not think you would want us to do that. Yet, if it is the law, it is a danger that it might happen or effectively happen that way, and I think that would be nonproductive. How we strike that balance, again, is a tough judgment call.

Mr. FUQUA. I recall a conversation that we had in Japan. Our colleague, Mr. McCurdy, was with us, with some students at Tokyo University, most of whom had studied at some point in the United States. They were asking about comparative school systems, and so forth. They thought their undergraduate program was probably superior to the United States and the graduate programs were probably about equal. But once in the United States, someone had their Ph.D. and was a researcher, the real secret was the innovative characteristic and the freedom to pursue the research projects in the United States that made us way ahead of them and their system. That is a very significant thing in this country, and it has some application in this area, that we do not get overspecific in exactly what has to be done.

There are probably some "white elephants" out there, as you were talking about awhile ago, and we have to find out where they are, and if they are, get rid of them. But those that we find through the technical people that we find have promise, then certainly they should be pursued in an orderly fashion. We were talking about the 5-year plan, and I think it is an excellent idea. We were hoping for a 3-year authorization bill this year. You cannot turn off and on research or demonstration, and that is one of the problems we have had. It is very wasteful. You cannot have it going up and down like a window shade. If it is good, support it; if it is bad, throw it out. That is why we hire you people and why we have a Department of Energy and all our national labs and universities and all those, to help advise us on those technical decisions.

I did not mean to make a speech. Mr. McCurdy, do you have any questions?

Mr. McCURDY. No questions, Mr. Chairman.

Mr. FUQUA. Thank you very much, Mr. Vaughan, Mr. Bauer, and Mr. Walsh. We appreciate your being here this morning, and we look forward to working with you. I think you are making significant improvements in the programs, and we look forward to working with you in a cooperative spirit.

The subcommittee will stand adjourned.

[Whereupon, at 11:30 a.m., the committee recessed, to reconvene at the call of the Chair.]

[Questions and answers submitted for the record follow:]

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
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JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
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FREDERICK C. BOUCHER, VA.

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DAVID S. JEFFERY
Minority Staff Director

February 15, 1984

Hon. William A. Vaughan
Asst. Secretary for Fossil Energy
Department of Energy
Washington, D.C. 20585

Dear Mr. Vaughan:

Attached are a number of questions regarding the Department's FY 1985 budget request for fossil energy research and development. The answers will be most helpful to the Committee as it marks up the FY 1985 DOE Civilian Research and Development Authorization next month.

We appreciate your willingness to testify before the Subcommittee on Energy Development and Applications on March 6, and would like to have your written answers to the enclosed questions no later than that date.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Kcw
attahcment

**Department of Energy**
**Washington, D.C. 20585**

March 6, 1984

Honorable Don Fuqua
Chairman, Subcommittee on Energy
  Development and Applications
Committee on Science and Technology
House of Representatives
Washington, D.C.  20515

Dear Mr. Chairman:

With your February 15, 1984, letter to William A. Vaughan, Assistant Secretary for Fossil Energy, you submitted written questions for response in connection with his appearance on March 7, 1984, before your Subcommittee concerning the authorization for fossil energy. Enclosed are answers to those questions.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

# PREHEARING QUESTIONS AND ANSWERS

RELATING TO THE

MARCH 7, 1984

HEARING ON AUTHORIZATION FOR FOSSIL ENERGY

BEFORE THE

SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

WITNESSES: WILLIAM VAUGHAN AND DONALD BAUER

GENERAL

Question #1: Please provide for each technology heading, such as Coal Preparation, Flue Gas Cleanup, Gas Stream Cleanup, etc., a breakdown of the dollar requirements for each of 1984 and 1985 on two bases: first, the major technology categories within those headings and second, the major contractor organizations under these headings.

Answer: The attached charts summarize the requested information.

Attachment A

## Major Technology Categories
($ in thousands)

| | FY 1984 | FY 1985 |
|---|---|---|
| **Control Tech. & Coal Prep.** | | |
| o Flue Gas Cleanup | | |
| - Program planning, development, support and analysis | 1,920 | 1,150 |
| - Control technology for western coals | 875 | 850 |
| - Applied research | 1,134 | 1,100 |
| - Process development | 3,409 | 4,700 |
| - Acid rain control | 0 | 5,225 |
| - Advanced concepts | 762 | 1,000 |
| Total | $ 8,100 | $14,025 |
| o Gas Stream Cleanup | | |
| - Turbine cleanup systems | 4,135 | 2,735 |
| - Molten carbonate fuel cell cleanup | 1,980 | 1,510 |
| - Process modification | 885 | 730 |
| Total | $ 7,000 | $ 4 975 |
| o Waste Management | | |
| - Scientific characterization | 1,755 | 725 |
| - Information systems | 695 | 225 |
| - Technology development | 225 | 850 |
| - Institutional analysis | 225 | 200 |
| Total | $ 2,900 | $ 2,000 |
| o Coal Preparation | | |
| - Physical beneficiation | 2,200 | 5,500 |
| - Chemical beneficiation | 1,600 | 3,500 |
| - Ancillary operations | 3,000 | 1,500 |
| - Coal characterization | 1,200 | 650 |
| Total | $ 8,000 | $11,150 |
| **Adv. Research & Tech. Development** | | |
| o Direct Utilization | | |
| - Coal combustion science | 3,116 | 3,300 |
| - Coal properties | 1,282 | 600 |
| - Erosion, corrosion & deposition mechanisms | 1,258 | 1,850 |
| - Separations processes | 1,644 | 2,410 |
| - Fuel cell research | 4,000 | 2,000 |
| Total | $11,300 | $10,160 |
| o Materials | | |
| - Structural ceramics | 1,350 | 1,475 |
| - Slag/refractory interactions | 1,750 | 1,535 |
| - High temperature corrosion | 2,815 | 2,085 |
| - Erosion and wear | 1,085 | 1,485 |
| Total | $ 7,000 | $ 6,580 |
| o Components | | |
| - Component concepts | 1,000 | 1,000 |
| - Solids transport | 0 | 477 |
| Total | $ 1,000 | $ 1,477 |
| o Processes | | |
| - Liquefaction processes | 4,350 | 4,725 |
| - Gasification processes | 3,650 | 3,800 |
| - Thermophysical properties | 1,000 | 1,500 |
| Total | $ 9,000 | $10,025 |

| | FY 1984 | FY 1985 |
|---|---|---|
| Adv. Research & Tech. Development (cont'd) | | |
| o Technology Crosscut | | |
| - Environmental activities | 1,750 | 2,500 |
| - Technical & economic analyses | 2,100 | 2,500 |
| - Technology base synthesis | 600 | 1,000 |
| - Instrumentation, control, and diagnostics | 2,500 | 1,525 |
| Total | $ 6,950 | $ 7,525 |
| o University Coal Research | | |
| - University research projects | $ 4,000 | $ 4,500 |
| Coal Liquefaction | | |
| o Indirect Liquefaction | | |
| - MTG pilot plant | 1,000 | 0[1] |
| - Liquid phase methanol facility | 0[1] | 0 |
| - Catalyst and slurry phase reaction | 6,900 | 2,500 |
| Total | $ 7,900 | $ 2,500 |
| o Advanced Process Development | | |
| - Wilsonville two-stage liquefaction | 6,500 | 0 |
| - Bench scale testing of an integrated two-stage liquefaction process | 1,500 | 0 |
| - Advanced direct liquefaction process concepts | 7,500 | 5,600 |
| Total | $15,500 | $ 5,600 |
| o Support Studies/Engineering Evaluations | | |
| - Biochemical studies and analagous fractions from single stage processes | 1,200 | 1,200 |
| - Guidance and process analysis studies; components and instrumentation | 1,900 | 1,900 |
| - Liquefaction data base management activities | 200[1] | 800 |
| - Coal dissolution reaction kinetics and mechanisms | 900 | 900 |
| - Environment, health and safety | 1,300 | 1,000 |
| Total | $ 5,500 | $ 5,800 |
| Combustion Systems | | |
| o Atmospheric Fluidized Bed | | |
| - Advanced AFB conceptual designs | 800 | 1,500 |
| - Fluidization research, model validation, data base analysis | 600 | 1,000 |
| - TVA AFB demo. | 0 | 15,000 |
| Total | $ 1,400 | $17,500 |
| o Pressurized Fluidized Bed | | |
| - IEA/Grimethorpe | 1,500 | 0 |
| - NYU, CURL & GE-LTMT | 2,600 | 1,400 |
| - PFB combined cycle pilot plant | 0[1] | 2,500 |
| - Data base analysis | 1,800 | 700 |
| - Fluidization research and systems analysis | 1,600 | 400 |
| Total | $ 7,500 | $ 5,000 |

[1] Activities supported with prior year funding.

| | FY 1984 | FY 1985 |
|---|---|---|
| Combustion Systems (cont'd) | | |
| o Alternative Fuels | | |
| - Coal-water mixtures characterization for utility and large industrial applications | 3,800 | 3,500 |
| - Characterization of other coal-liquid mixtures for institutional/residential applications | 2,400 | 1,000 |
| - Coal-liquid mixtures applicable to advanced combustion systems | 1,400 | 1,500 |
| - Emissions characterization from CLM use | 0 | 1,175 |
| Total | $ 7,600 | $ 7,175 |
| o Advanced Combustion Technology | | |
| - Partially developed advanced slagging coal combustors | 1,300 | 1,600 |
| - Innovative concepts and non-slagging combustors | 400 | 400 |
| Total | $ 1,700 | $ 2,000 |
| Fuel Cells | | |
| o Advanced Concepts | | |
| - Technology base | 0 | 458 |
| - Solid oxide fuel cells | 2,000 | 1,942 |
| - Thermionics (mgmt. of program transferred to DOE Office of Nuclear Energy) | 2,600 | 0 |
| Total | $ 4,600 | $ 2,400 |
| o Molten Carbonate Systems | | |
| - Short stack development | 4,000 | 2,252 |
| - Integrated components | 2,000 | 0 |
| - Internal fuel reforming concepts | 1,700 | 700 |
| - Technology base | 1,500 | 1,148 |
| Total | $ 9,200 | $ 4,100 |
| o Phosphoric Acid Systems | | |
| - Electric utility program | 20,499 | 4,400 |
| - On-site program | 5,975 | 1,400 |
| - Technology base | 2,326 | 1,400 |
| Total | $28,800 | $ 7,200 |
| Heat Engines | | |
| o Coal-fired gas turbine program | 5,500 | 5,200 |
| o Coal-fired diesel engine program | 1,000 | 2,450 |
| Total | $ 6,500 | $ 7,650 |
| Underground Coal Gasification | | |
| o Gasification Technology Development | | |
| - Subbituminous coal | 3,000 | 2,050 |
| - Bituminous coal | 800 | 1,000 |
| - International agreement | 100 | 100 |
| Total | $ 3,900 | $ 3,150 |
| o Environmental and Advanced Research | | |
| - Environmental monitoring | 700 | 700 |
| - Environmental mitigation research | 1,200 | 1,200 |
| - Process modeling | 200 | 800 |
| Total | $ 2,100 | $ 2,700 |

| | FY 1984 | FY 1985 |
|---|---|---|
| **Magnetohydrodynamics** | | |
| o Closed-Cycle Systems | | |
| - Technical support | 105 | 0 |
| Total | $ 105 | $ 0 |
| o Open-Cycle Systems | | |
| - CDIF | 8,350 | 0 |
| - Engineering development | 17,200 | 7,000 |
| - Coal combustors | (3,200) | 0 |
| - HRSR and seed regeneration | (6,268) | 0 |
| - Instrumentation | (2,000) | 0 |
| - Channel | (5,442) | 0 |
| - Superconducting magnets | (290) | 0 |
| - Integrated power system test | (0) | (7,000) |
| - Systems engineering | 3,400 | 0 |
| - Supporting research | 945 | 10,800 |
| - Combustion research | 0 | (3,000) |
| - Channel research | 0 | (2,400) |
| - Superconducting magnets | 0 | (800) |
| - Power conditioning | 0 | (800) |
| - Seed regeneration | 0 | (1,400) |
| - Instrumentation | 0 | (1,800) |
| - Systems analysis | 0 | (600) |
| Total | $29,895 | $17,800 |
| Surface Coal Gasification | | |
| o Advanced Process Development | | |
| - Innovative concepts - gasifier operation | 2,093 | 1,800 |
| - Advanced concepts - ancillary processing | 3,448 | 1,640 |
| - Coal gasification technology base | 1,409 | 1,010 |
| Total | $ 6,950 | $ 4,450 |
| o Systems Engineering Concepts | | |
| - Gasifier systems | 19,400 | 1,965 |
| - Equipment, instrumentation, materials concepts | 3,000 | 2,010 |
| Total | $22,400 | $ 3,975 |
| o Environmental Studies & Engineering Analyses | | |
| - Environmental studies (waste water management, characterization of process streams, novel environmental effluent control technology) | 3,400 | 2,500 |
| - Engineering studies/technology data base | 1,000 | 1,075 |
| Total | $ 4,400 | $ 3,575 |
| o Great Plains Coal Gasification Project | | |
| - Management and monitoring | 3,040 | 3,000 |
| Total | $ 3,040 | $ 3,000 |
| Unconventional Gas Recovery | | |
| o Eastern Gas Shales | | |
| - Reservoir property measurements | 1,000 | 1,000 |
| - Shale data base collection | 500 | 500 |
| - Offset well facility | 2,000 | 0 |
| Total | $ 3,500 | $ 1,500 |

| | FY 1984 | FY 1985 |
|---|---|---|
| Unconventional Gas Recovery (cont'd) | | |
| o Western Tight Gas Sands | | |
| - Fracture stimulation research ................ | 4,000 | 4,000 |
| - Generic supporting research .................. | 2,750 | 750 |
| - Geologic basin analyses & geophysical research | 750 | 0 |
| - Formation damage research .................... | 500 | 0 |
| Total .................................. | $ 8,000 | $ 4,750 |
| o Environmental & Advanced Research | | |
| - Gas hydrates and deep source gas research .... | 1,250 | 1,900 |
| - Coalbed methane .............................. | 0 | 100 |
| - Reservoir/production modeling ................ | 750 | 200 |
| - Methane and/or carbon transport studies ...... | 0 | 100 |
| Total .................................. | $ 2,000 | $ 2,300 |
| o Geopressured Methane | | |
| - Geopressured methane research ................ | 2,000 | 0 |
| Total .................................. | $ 2,000 | $ 0 |
| Enhanced Oil Recovery | | |
| o Heavy Oil | | |
| - Data base maintenance ........................ | 200 | 620 |
| - Fundamental research ......................... | 980 | 1,200 |
| - Investigate role of clays .................... | 100 | 300 |
| - High temperature research .................... | 0 | 300 |
| - International research ....................... | 320 | 580 |
| Total .................................. | $ 1,600 | $ 3,000 |
| o Light Oil | | |
| - Data base maintenance ........................ | 710 | 1,100 |
| - Fundamental research ......................... | 3,800 | 5,150 |
| - Gas miscible flooding research ............... | 900 | 1,450 |
| - Supporting research .......................... | 1,060 | 1,500 |
| Total .................................. | $ 6,550 | $ 9,200 |
| o Tar Sands | | |
| - Develop fundamental recovery concepts ........ | 500 | 600 |
| - Research recovery of tar sand bitumen ........ | 0 | 200 |
| - Process development and environmental impact activities ............................ | 500 | 400 |
| Total .................................. | $ 1,000 | $ 1,200 |
| Advanced Process Technology | | |
| o Advanced Exploratory Research | | |
| - Advanced extraction technology ............... | 1,300 | 1,500 |
| - Fundamental petroleum chemistry .............. | 1,900 | 2,000 |
| - Advanced utilization technology .............. | 800 | 1,000 |
| Total .................................. | $ 4,000 | $ 4,500 |
| o Arctic and Offshore Research | | |
| - Data collection .............................. | 225 | 475 |
| - Data maintenance ............................. | 450 | 450 |
| - Fundamental research on ice mechanics and seafloor stability ........................... | 325 | 775 |
| Total .................................. | $ 1,000 | $ 1,700 |

| | FY 1984 | FY 1985 |
|---|---|---|
| Oil Shale | | |
| o Technology Base | | |
| - Chemistry and physics ........................ | 3,000 | 2,600 |
| - Fragmentation ................................ | 2,800 | 1,600 |
| - Novel concepts ............................... | 3,850 | 1,800 |
| Total ................................ | $ 9,650 | $ 6,000 |
| o Environmental Mitigation | | |
| - Characterize off-gas emissions from retorting processes ................................. | 500 | 1,000 |
| - Environmental studies ........................ | 3,500 | 3,000 |
| - Research waste water pollutants and cleanup systems .................................... | 1,000 | 1,300 |
| - Research trace elements as a function of retort operating parameters .................. | 1,500 | 700 |
| Total ................................ | $ 6,500 | $ 6,000 |

Attachment B

## Major Contractor Organizations
($ in thousands)

| | FY 1984 | | | | | FY 1985 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Procurement | ETC In-House | Cooperative Agreement | Lab | Total | Procurement | ETC In-House | Cooperative Agreement | Lab | Total |
| **Control Tech. & Coal Prep.** | | | | | | | | | | |
| Flue Gas Cleanup | 4,890 | 1,900 | 650 | 660 | 8,100 | 11,725 | 1,000 | 650 | 650 | 14,025 |
| Gas Stream Cleanup | 5,780 | 425 | 0 | 795 | 7,000 | 3,850 | 1,125 | 0 | 0 | 4,975 |
| Waste Management | 1,560 | 400 | 250 | 690 | 2,900 | 900 | 350 | 250 | 500 | 2,000 |
| Coal Preparation | 4,459 | 1,641 | 500 | 1,400 | 8,000 | 8,000 | 1,650 | 500 | 1,000 | 11,150 |
| Total | 16,689 | 4,366 | 1,400 | 3,545 | 26,000 | 24,475 | 4,125 | 1,400 | 2,150 | 32,150 |
| **Adv. Res. & Tech. Dev.** | | | | | | | | | | |
| Direct Utilization | 6,715 | 1,120 | 875 | 2,590 | 11,300 | 5,870 | 1,890 | 1,250 | 1,150 | 10,160 |
| Materials & Components | 552 | 600 | 0 | 6,848 | 8,000 | 1,212 | 0 | 0 | 6,845 | 8,057 |
| Processes | 4,480 | 2,500 | 1,090 | 930 | 9,000 | 5,575 | 2,500 | 1,250 | 700 | 10,025 |
| Technology Crosscut | 4,060 | 950 | 0 | 1,940 | 6,950 | 5,275 | 600 | 0 | 1,650 | 7,525 |
| University Coal Research | 4,000 | 0 | 0 | 0 | 4,000 | 4,500 | 0 | 0 | 0 | 4,500 |
| Total | 19,807 | 5,170 | 1,965 | 12,308 | 39,250 | 22,432 | 4,990 | 2,500 | 10,345 | 40,267 |
| **Coal Liquefaction** | | | | | | | | | | |
| Indirect Liquefaction | 5,650 | 2,000 | 0 | 250 | 7,900 | 1,500 | 1,000 | 0 | 0 | 2,500 |
| Advanced Process Devmt. | 13,100 | 1,200 | 1,200 | 0 | 15,500 | 3,500 | 1,200 | 900 | 0 | 5,600 |
| Spt. Studies/Engrg. Evl. | 2,100 | 400 | 0 | 3,000 | 5,500 | 3,100 | 1,000 | 0 | 1,700 | 5,800 |
| Total | 20,850 | 3,600 | 1,200 | 3,250 | 28,900 | 8,100 | 3,200 | 900 | 1,700 | 13,900 |
| **Combustion Systems** | | | | | | | | | | |
| Atmos. Fluid. Bed Comb. | 1,000 | 400 | 0 | 0 | 1,400 | 15,965 | 535 | 1,000 | 0 | 17,500 |
| Press. Fluid. Bed Comb. | 6,250 | 500 | 600 | 150 | 7,500 | 4,025 | 975 | 0 | 0 | 5,000 |
| Alternative Fuels | 4,992 | 2,308 | 300 | 0 | 7,600 | 5,025 | 1,650 | 400 | 100 | 7,175 |
| Adv. Comb. Tech. | 1,550 | 0 | 0 | 150 | 1,700 | 1,700 | 300 | 0 | 0 | 2,000 |
| Total | 13,792 | 3,208 | 900 | 300 | 18,200 | 26,715 | 3,460 | 1,400 | 100 | 31,675 |
| **Fuel Cells** | | | | | | | | | | |
| Advanced Concepts | 4,428 | 0 | 0 | 172 | 4,600 | 2,100 | 0 | 0 | 300 | 2,400 |
| Molten Carb. Sys. | 8,400 | 400 | 0 | 400 | 9,200 | 3,525 | 0 | 0 | 575 | 4,100 |
| Phos. Acid Sys. | 28,600 | 0 | 0 | 200 | 28,800 | 6,950 | 0 | 0 | 250 | 7,200 |
| Total | 41,428 | 400 | 0 | 772 | 42,600 | 12,575 | 0 | 0 | 1,125 | 13,700 |
| **Heat Engines** | | | | | | | | | | |
| Heat Engines | 5,600 | 800 | 0 | 100 | 6,500 | 6,650 | 1,000 | 0 | 0 | 7,650 |
| Total | 5,600 | 800 | 0 | 100 | 6,500 | 6,650 | 1,000 | 0 | 0 | 7,650 |

### Major Contractor Organizations
($ in thousands)

| | FY 1984 | | | | | FY 1985 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Procurement | ETC In-House | Cooperative Agreement | Lab | Total | Procurement | ETC In-House | Cooperative Agreement | Lab | Total |
| **Underground Coal Gasif.** | | | | | | | | | | |
| Gasif. Tech. Development | 0 | 0 | 0 | 0 | 0 | 1,650 | 200 | 0 | 1,300 | 3,150 |
| Environ. & Adv. Research | 1,545 | 0 | 2,000 | 2,425 | 6,000 | 700 | 0 | 2,000 | 0 | 2,700 |
| Total | 1,545 | 0 | 2,000 | 2,425 | 6,000 | 2,350 | 200 | 2,000 | 1,300 | 5,850 |
| **Magnetohydrodynamics** | | | | | | | | | | |
| Closed-Cycle Systems | 105 | 0 | 0 | 0 | 105 | 0 | 0 | 0 | 0 | 0 |
| Open-Cycle Plasma Systems | 28,805 | 0 | 0 | 1,090 | 29,895 | 16,900 | 200 | 0 | 700 | 17,800 |
| Total | 28,910 | 0 | 0 | 1,090 | 30,000 | 16,900 | 200 | 0 | 700 | 17,800 |
| **Surface Coal Gasification** | | | | | | | | | | |
| Adv. Process Dev. | 5,065 | 600 | 800 | 485 | 6,950 | 3,550 | 900 | 0 | 0 | 4,450 |
| Systems Eng. Concepts | 18,615 | 1,560 | 400 | 1,825 | 22,400 | 3,400 | 575 | 0 | 0 | 3,975 |
| Environ/Engrg. Analyses | 1,000 | 1,750 | 900 | 750 | 4,400 | 1,375 | 700 | 1,100 | 400 | 3,575 |
| Great Plains Project | 2,739 | 100 | 0 | 201 | 3,040 | 2,400 | 600 | 0 | 0 | 3,000 |
| Total | 27,419 | 4,010 | 2,100 | 3,261 | 36,790 | 10,725 | 2,775 | 1,100 | 400 | 15,000 |
| **Unconventional Gas Recovery** | | | | | | | | | | |
| Eastern Gas Shales | 3,500 | 0 | 0 | 0 | 3,500 | 1,150 | 350 | 0 | 0 | 1,500 |
| Western Tight Gas Sands | 5,798 | 0 | 500 | 1,702 | 8,000 | 2,800 | 350 | 0 | 1,600 | 4,750 |
| Environ. & Adv. Research | 1,780 | 220 | 0 | 0 | 2,000 | 1,600 | 400 | 0 | 300 | 2,300 |
| Geopressured Methane | 2,000 | 0 | 0 | 0 | 2,000 | 0 | 0 | 0 | 0 | 0 |
| Total | 13,078 | 220 | 500 | 1,702 | 15,500 | 5,550 | 1,100 | 0 | 1,900 | 8,550 |
| **Advanced Process Tech.** | | | | | | | | | | |
| Adv. Exploratory Research | 1,100 | 0 | 2,300 | 600 | 4,000 | 1,000 | 0 | 3,000 | 500 | 4,500 |
| Arctic & Offshore Res. | 775 | 0 | 0 | 225 | 1,000 | 1,350 | 150 | 0 | 200 | 1,700 |
| Total | 1,875 | 0 | 2,300 | 825 | 5,000 | 2,350 | 150 | 3,000 | 700 | 6,200 |
| **Enhanced Oil Recovery** | | | | | | | | | | |
| Heavy Oil | 1,180 | 0 | 220 | 200 | 1,600 | 2,400 | 0 | 0 | 600 | 3,000 |
| Light Oil | 2,000 | 550 | 4,000 | 0 | 6,550 | 3,950 | 700 | 4,550 | 0 | 9,200 |
| Tar Sands | 45 | 0 | 955 | 0 | 1,000 | 200 | 0 | 1,000 | 0 | 1,200 |
| Total | 3,225 | 550 | 5,175 | 200 | 9,150 | 6,550 | 700 | 5,550 | 600 | 13,400 |
| **Oil Shale** | | | | | | | | | | |
| Oil Shale Tech. Base | 4,188 | 450 | 2,002 | 3,010 | 9,650 | 1,201 | 527 | 1,922 | 2,350 | 6,000 |
| Environ. Mitigation | 2,283 | 300 | 2,490 | 1,427 | 6,500 | 1,700 | 497 | 2,032 | 1,771 | 6,000 |
| Total | 6,471 | 750 | 4,492 | 4,437 | 16,150 | 2,901 | 1,024 | 3,954 | 4,121 | 12,000 |

## GENERAL

Question #2: For each major program area, e.g. magnetohydrodynamics, surface coal gasification, etc., please generally describe those activities you expect to continue in FY 1986 and FY 1987 in conjunction with your projections for those years provided to the Controller's Office. To the extent that particular large projects or subprogram areas increase or decrease in those projections, please describe those fluctuations.

Answer: With the exception of the Phosphoric Acid Fuel Cells (PAFC) program and the TVA/PFB Demonstration plant project, existing Fossil Energy programs are planned to continue at generally constant funding levels (adjusted for inflation). The Federal role in the development of Phosphoric Acid Fuel Cell (PAFC) technologies is expected to diminish after FY 1985. The 4.8 Mw preprototype PAFC plant and the 40 kw field test project are already fully funded. The 11 Mw PAFC technology development program is expected to be completed in the FY 1985 time frame. Further development is anticipated to be carried out by the private sector. The 7.5 Mw on-site development activities are expected to be completed in the FY 1986/1987 time frame. Also, Federal funding for the "alternate" on-site technology development project is not expected to continue beyond FY 1984.

The TVA/PFB Demonstration project is funded at $15,000,000 in FY 1985 and $15,000,000 in FY 1986. Fossil Energy is not anticipating requesting any additional funding beyond FY 1986 for this project.

## GENERAL

Question #3: For each of the energy technology centers for FY 1984 and FY 1985, please provide the total dollars for which they are responsible by major program area. Within those areas please also provide the amounts that are assigned to internal energy technology center research, to industrial research, to universities, and to national labs, to the detail that is available to the Department.

Answer: The data requested is provided in the attached tables. Shown for both FY 1984 and FY 1985 are each Center's in-house research (internal energy technology center research), procurement (industrial research), and laboratory funding. Headquarters procurements are shown separately. For FY 1984, the amount of university contracts are shown by major program. Final FY 1985 university contract data is not available at this time. However, it is anticipated that if one compares funds devoted to university related research to total new budget authority for Fossil Energy, the overall funding for universities will be about the same as FY 1984.

## ETC's INHOUSE & INDIVIDUAL PROCUREMENTS

FY 1984
($000)

| LEAD CENTERS | METC/ PETC | 1/ | PETC | METC/ PETC | METC | METC | METC | PETC | 2/ | METC | BPO/ METC | BPO/ METC | METC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B&R # PROGRAM | AA05 CTCP | AA15 AR&TD | AA25 LIQUEF | AA35 COMB | AA45 FUELCEL | AA55 HE | AA65 UCG | AA70 MHD | AA85 SURFGAS | AB05 UGR | AC05 APT | AC15 EOR | AC20 SHALE |
| METC | | | | | | | | | | | | | |
| In-House | 725 | 2,370 | 0 | 1,200 | 400 | 800 | 0 | 0 | 3,390 | 220 | 0 | 550 | 750 |
| Procurements 3/ | 6,819 | 6,499 | 0 | 5,832 | 28,396 | 5,250 | 825 | 0 | 23,379 | 10,603 | 682 | 350 | 3,410 |
| (University) | (1,657) | (2,340) | 0 | (1,960) | (7) | (47) | (2,045) | 0 | (2,859) | (1,493) | (500) | (955) | (4,930) |
| Labs | 1,485 | 1,575 | 0 | 150 | 772 | 100 | 2,425 | 0 | 3,060 | 1,702 | 225 | 0 | 4,437 |
| Total | 9,029 | 10,444 | 0 | 7,182 | 29,568 | 6,150 | 3,250 | 0 | 29,829 | 12,525 | 907 | 900 | 8,597 |
| PETC | | | | | | | | | | | | | |
| In-House | 3,641 | 2,800 | 3,600 | 2,308 | 0 | 0 | 0 | 0 | 620 | 0 | 0 | 0 | 0 |
| Procurements 3/ | 5,809 | 8,892 | 19,187 | 5,790 | 0 | 0 | 0 | 11,566 | 0 | 0 | 0 | 0 | 0 |
| (University) | (1,373) | (7,460) | (1,721) | 0 | 0 | 0 | 0 | (650) | 0 | 0 | 0 | 0 | 0 |
| Labs | 2,060 | 330 | 3,250 | 150 | 0 | 0 | 0 | 1,090 | 0 | 0 | 0 | 0 | 0 |
| Total | 11,510 | 12,022 | 26,037 | 8,248 | 0 | 0 | 0 | 12,656 | 620 | 0 | 0 | 0 | 0 |
| BPO | | | | | | | | | | | | | |
| In-House | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Procurements 3/ | 0 | 100 | 0 | 0 | 0 | 200 | 0 | 0 | 0 | 0 | 950 | 1,850 | 0 |
| (University) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Labs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 600 | 200 | 0 |
| Total | 0 | 100 | 0 | 0 | 0 | 200 | 0 | 0 | 0 | 0 | 1,550 | 2,050 | 0 |
| Other Procurement Offices & Labs | 5,461 | 16,684 | 2,863 | 2,770 | 13,032 | 150 | 2,750 | 17,344 | 6,341 | 2,975 | 2,543 | 6,200 | 7,553 |
| Grand Total | 26,000 | 39,250 | 28,900 | 18,200 | 42,600 | 6,500 | 6,000 | 30,000 | 36,790 | 15,500 | 5,000 | 9,150 | 16,150 |

1/ In the AR&TD program, overall direction is provided by Headquarters.

2/ In the Surface Coal Gasification program, the lead center is METC with the exception of the subprogram, Great Plains Gasification Project, where METC shares supervision with Headquarters.

3/ Includes procurements at ETC's and Operations Offices. University contracts are included in procurements.

ETC's INHOUSE & INDIVIDUAL PROCUREMENTS

FY 1985
($000)

| LEAD CENTERS | METC/ PETC | 1/ | PETC | METC/ PETC | METC | METC/ BPO | METC | PETC | 2/ | METC | BPO/ METC | BPO/ METC | METC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B&R # PROGRAM | AA05 CTCP | AA15 AR&TD | AA25 LIQUEF | AA35 COMB | AA45 FUELCEL | AA55 HE | AA65 UCG | AA70 MHD | AA85 SURFGAS | AB05 UGR | AC05 APT | AC15 EOR | AC20 SHALE |
| METC | | | | | | | | | | | | | |
| In-House | 1,375 | 1,540 | 0 | 1,660 | 0 | 1,000 | 200 | 0 | 2,075 | 1,100 | 150 | 700 | 1,024 |
| Procurements 3/ | 4,290 | 3,585 | 0 | 2,410 | 6,675 | 6,045 | 1,046 | 0 | 7,650 | 4,642 | 1,149 | 800 | 900 |
| Labs | 500 | 1,450 | 0 | 0 | 1,125 | 0 | 1,300 | 0 | 400 | 1,900 | 200 | 0 | 4,121 |
| Total | 6,165 | 6,575 | 0 | 4,070 | 7,800 | 7,045 | 2,546 | 0 | 10,125 | 7,642 | 1,499 | 1,500 | 6,045 |
| PETC | | | | | | | | | | | | | |
| In-House | 2,750 | 3,450 | 3,200 | 1,800 | 0 | 0 | 0 | 200 | 700 | 0 | 0 | 0 | 0 |
| Procurements 3/ | 17,863 | 10,870 | 6,139 | 5,545 | 0 | 0 | 0 | 15,725 | 0 | 0 | 0 | 0 | 0 |
| Labs | 1,650 | 400 | 1,700 | 100 | 0 | 0 | 0 | 700 | 0 | 0 | 0 | 0 | 0 |
| Total | 22,263 | 14,720 | 11,039 | 7,445 | 0 | 0 | 0 | 16,625 | 700 | 0 | 0 | 0 | 0 |
| BPO | | | | | | | | | | | | | |
| In-House | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Procurements 3/ | 0 | 75 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 808 | 3,566 | 0 |
| Labs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 500 | 600 | 0 |
| Total | 0 | 75 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 1,308 | 4,166 | 0 |
| Other Procurment Offices | 3,722 | 18,897 | 2,861 | 20,160 | 5,900 | 505 | 3,304 | 1,175 | 4,175 | 908 | 3,393 | 7,734 | 5,955 |
| Grand Total | 32,150 | 40,267 | 13,900 | 31,675 | 13,700 | 7,650 | 5,850 | 17,800 | 15,000 | 8,550 | 6,200 | 13,400 | 12,000 |

1/ In the AR&TD program, overall direction is provided by Headquarters.

2/ In the Surface Coal Gasification program, the lead center is METC with the exception of the subprogram, Great Plains Gasification Project, where METC shares supervision with Headquarters.

3/ Includes procurements at ETC's and Operations Offices. University contracts are included in procurements.

## GENERAL

Question #4: Please provide a breakout of fossil energy personnel for FY 1984 and FY 1985 by headquarters and ETC functions, and explain why decreases are being recommended in these areas. What legislative changes are necessary, if any, in order to implement these decreases?

Answer: The following is a breakout of Fossil Energy Full Time Equivalent (FTE) staffing by Headquarters and Energy Technology Center for FY 1984 and FY 1985:

| Organization | FY 1984<br>FTE | FY 1985<br>FTE |
|---|---|---|
| Headquarters | 157 | 127 |
| Morgantown Energy Technology Center[1/] | 279 | 250 |
| Pittsburgh Energy Technology Center | 286 | 250 |
| Bartlesville Project Office | 15 | 10 |
| | 737 | 637 |

1/ Includes FTE's at Laramie Project Office and Grand Forks Project Office.

The staffing level of 737 FTEs for FY 1984 provides sufficient personnel for compliance with the Congressional floor of 715 FTP employees mandated by Public Law 98-63. The request for 637 FTEs for FY 1985 represents the staffing level needed by the Department to effectively manage the fossil energy program. In order to achieve the personnel levels requested in the Fossil Energy Congressional Budget Request, it is assumed that legislation will be enacted to repeal or revise the employment floor in Public Law 98-63 and Public Law 97-257. The Department has requested such legislation. Until Public Law 98-63 and Public Law 97-257 are changed, the Department will comply with the legislative requirements regarding personnel levels.

GENERAL

Question #5: Please provide a breakout for FY 1984 and FY 1985 of the dollars by technology that are available to each of the former Energy Technology Centers at Bartlesville, OK; Grand Forks, ND; and Laramie, WY.

Answer: The following is a breakout by technology for FY 1984 and FY 1985 of the funding available at the Bartlesville Project Office (BPO), the Grand Forks Project Office (GFPO), and the Laramie Project Office (LPO). (See Attachments 1 and 2)

Attachment 1

FY 1984
($000)

| B&R # PROGRAM | AA05 CTCP | AA15 AR&TD | AA25 LIQUEF | AA35 COMB | AA45 FUELCEL | AA55 HE | AA65 UCG | AA70 MHD | AA85 SURFGAS | AB05 UGR | AC05 APT | AC15 EOR | AC20 SHALE | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COOP[1] | 0 | 480 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 500 | 2000 | 4220 | 0 | 7200 |
| PROC[2] | 0 | 100 | 0 | 0 | 0 | 200 | 0 | 0 | 0 | 0 | 950 | 1850 | 0 | 3100 |
| T/BPO | 0 | 580 | 0 | 0 | 0 | 200 | 0 | 0 | 0 | 500 | 2950 | 6070 | 0 | 10300 |
| COOP[1] | 1300 | 1485 | 1200 | 900 | 0 | 0 | 0 | 0 | 2100 | 0 | 0 | 0 | 0 | 6985 |
| PROC[2] | 485 | 575 | 0 | 275 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1335 |
| T/GFPO | 1785 | 2060 | 1200 | 1175 | 0 | 0 | 0 | 0 | 2100 | 0 | 0 | 0 | 0 | 8320 |
| COOP[1] | 100 | 0 | 0 | 0 | 0 | 0 | 2000 | 0 | 0 | 0 | 300 | 955 | 4492 | 7847 |
| PROC[2] | 0 | 0 | 0 | 0 | 0 | 0 | 506 | 0 | 0 | 0 | 0 | 0 | 2103 | 2609 |
| T/LPO | 100 | 0 | 0 | 0 | 0 | 0 | 2506 | 0 | 0 | 0 | 300 | 955 | 6595 | 10456 |

[1] COOP represents the funds associated with the Cooperative Agreements with Wyoming Research Institute, University of North Dakota, Illinois Institute of Technology and Research Institute.

[2] PROC represents the funds associated with procurement actions.

Attachment 2

FY 1985
($000)

| B&R # PROGRAM | AA05 CTCP | AA15 AR&TD | AA25 LIQUEF | AA35 COMB | AA45 FUELCEL | AA55 HE | AA65 UCG | AA70 MHD | AA85 SURFGAS | AB05 UGR | AC05 APT | AC15 EOR | AC20 SHALE | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COOP1/ | 0 | 700 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2500 | 4550 | 0 | 7750 |
| PROC2/ | 0 | 75 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 808 | 3566 | 0 | 4549 |
| T/BPO | 0 | 775 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 3308 | 8116 | 0 | 12299 |
| COOP1/ | 1400 | 1800 | 900 | 1400 | 0 | 0 | 0 | 0 | 1100 | 0 | 0 | 0 | 0 | 6600 |
| PROC2/ | 200 | 1000 | 0 | 325 | 0 | 0 | 0 | 0 | 500 | 0 | 0 | 0 | 0 | 2025 |
| T/GFPO | 1600 | 2800 | 900 | 1725 | 0 | 0 | 0 | 0 | 1600 | 0 | 0 | 0 | 0 | 8625 |
| COOP1/ | 0 | 0 | 0 | 0 | 0 | 0 | 2000 | 0 | 0 | 0 | 500 | 1000 | 3954 | 7454 |
| PROC2/ | 0 | 0 | 0 | 0 | 0 | 0 | 700 | 0 | 0 | 0 | 0 | 140 | 1156 | 1996 |
| T/LPO | 0 | 0 | 0 | 0 | 0 | 0 | 2700 | 0 | 0 | 0 | 500 | 1140 | 5110 | 9450 |

Note: The number indicated for FY 1985 are preliminary estimates and are subject to changes as the programs for FY 1985 become further defined.

1/ COOP represents the funds associated with the cooperatve agreements with Wyoming Research Institute, University of North Dakota, Illinois Institute of Technology.

2/ PROC represents the funds associated with procurement actions.

## GENERAL

Question #6: Please provide a breakout of where the $49,189,000 of unobligated balances to be used to offset FY 1985 program needs comes from, by program area.

Answer: The following table indicates the origin of the $49,189,000 in unobligated balances to be used to offset FY 1985 program needs:

| | | |
|---|---|---|
| Fossil Energy Construction (89X0214.40) | | |
| 79-1-R | SRC-II | $33,901,000 |
| 78-2-D | SRC-I | 2,000,000 |
| 76-1-B | High-Btu Pipeline | 1,263,000 |
| 77-1-B | High-Btu Pipeline | 17,000 |
| 76-1-C | Low/Med-Btu Pilot Plant | 15,000 |
| | Total Construction | $37,196,000 |
| Fossil Energy R&D (89X0213.91) | | |
| AA252515 | SRC-II | $ 4,743,000 |
| AB0525 | Geopressured Methane | 2,000,000 |
| AA8530 | Gasification Demo | 500,000 |
| | Headquarters Deobligations | |
| AA854505 | Surface Coal Gasif./Gasifier Systems (Foster Wheeler) | 103,000 |
| AA252505 | Coal Liquefaction/Demo Plants (Fluor Eng.) | 36,000 |
| AA252525 | Coal Liquefaction/Demo Plants (Coalcon) | 1,000,000 |
| AA253005 | Coal Liquefaction/Support Studies (Fluor) | 700,000 |
| AA152015 | Adv. Res. & Tech. Devmt./ Program Devmt. & Coord. (MITRE) | 107,000 |
| AA854505 | Surface Coal Gasif./Systems Engr. Concepts (Bituminous Coal Research) | 304,000 |
| | Total FE R&D | $ 9,493,000 |
| Energy Prod., Demo. & Distr. (89X0219.91) | | |
| CA20 | Coal Loan Guarantee | $ 2,500,000 |
| Total Deobligations | | $49,189,000 |

## GENERAL

Question #7: Please describe what management initiatives are being introduced that will save $12,150,000 in FY 1985.

Answer: The $12,150,000 in savings for FY 1985 is comprised of management initiatives in Financial Systems Reform and Administrative Organization Management.

Financial Systems Reform

This initiative will result in savings of $12,000,000 in FY 1985 through improved management of the deobligation of multi-year funds. Deobligations may occur due to contract close-outs, contractor defaults, or other instances of contractual dollar reductions, such as cost disallowances based on audit results. Under this initiative, such deobligations will be reported and evaluated to determine whether or not the funding should be retained in the program area where it was originally appropriated. If it is determined that there is no compelling reason to retain these funds in that program area, they will be deferred, if necessary (i.e., FY 1984 and previous year funding), and used to offset budget authority in FY 1985.

Organization and Management

This initiative will result in savings of $150,000 resulting from improved planning and control of organization structures within the Office of Fossil Energy. The implementation of this initiative will include Grace Commission guidance to managers on improved organization planning and special reviews of existing and proposed organization structures focusing on supervisor to employee ratios, reduction in the number of levels of supervision, and overall staffing resource utilization. The reduction in budget authority represents manpower savings.

## GENERAL

Question #8: In your budget justifications the term "proof of concept" occurs often. Please explain what type of facility this is and how it fits into the previous structure of bench scale unit, process development unit, and pilot plant. If the concept is different for different technologies, please also explain this.

Answer: "Proof of concept" refers to that phase of R&D where the technology has progressed from applied research through exploratory development into advanced development. Completion of "proof of concept" phase is the completion of the advanced development effort and a conditional verification of the technical and environmental feasibility prior to proceeding with the process development. The attached chart, entitled "Technology Development Path", illustrates the location of the "proof of concept" stage on the path between basic research and commercialization. "Proof of concept" is the point at which the technology base has been developed and technology transfer will occur into the private sector without any further government involvement. However, under certain conditions it may be necessary for the government to participate with industry in a cost sharing effort through a "Process Development Unit (PDU)/Subpilot" phase for complete technology verification. The size of the unit or process utilized for either the "proof of concept" or the "PDU/subpilot" will vary depending on the system or subsystem, its complexity, time to complete the verification, and overall cost to the government.

The following paragraphs provide a few examples of where "proof of concept" falls within the development path of various systems.

Waste Management - In the waste management area, a fixation stablization "proof of concept" activity would be much smaller than a "proof of concept" for leachability of a non-fixated disposal site. Commercialization will move rapidly after total technology verification has been completed at a sufficient size with the related economic data base necessary for private sector assessment of the commerical viability of the techniques and/or processes under consideration.

Flue Gas Cleanup - In the case of hot gas cleanup particulate removal, etc., a cyclone "proof of concept" test could be relatively smaller than say a ceramic base. Scale up risks are different for different cleanup technologies.

The term "proof of concept" as applied to the flue gas cleanup area connotes a test facility that utilizes a slip stream from a coal fired boiler that is on the order of 10,000 SCFM to 20,000 SCFM in size (5 to 10 MWe). The term process development unit has not in the past ordinarily been used to apply to flue gas cleanup technology. Full size scrubber modules are generally on the order of 100 to 150 MWe in size. Pilot plants are normally considered to be 1-10 percent of full scale with bench scale defined as less than 1 percent of full scale. By these definitions, the proof of concept scale would be approximately equivalent to pilot plant scale.

Heat Engines - As applied to engineering systems development in general, "proof of concept" fits logically between preliminary engineering bench tests (static test verification of fuel, design, and operating specifications) and true commercial prototype tests.

In the case of turbines, "proof of concept" would be based on successful operation of a small (less than 10 Mw) coal-fired engine under the specified conditions. In the case of coal-fueled diesels, "proof of concept" would similarly require the successful operation of a realistic test bed engine. In both instances, the "proof of concept" tests would be expected to provide a convincing basis for subsequent private sector prototype testing.

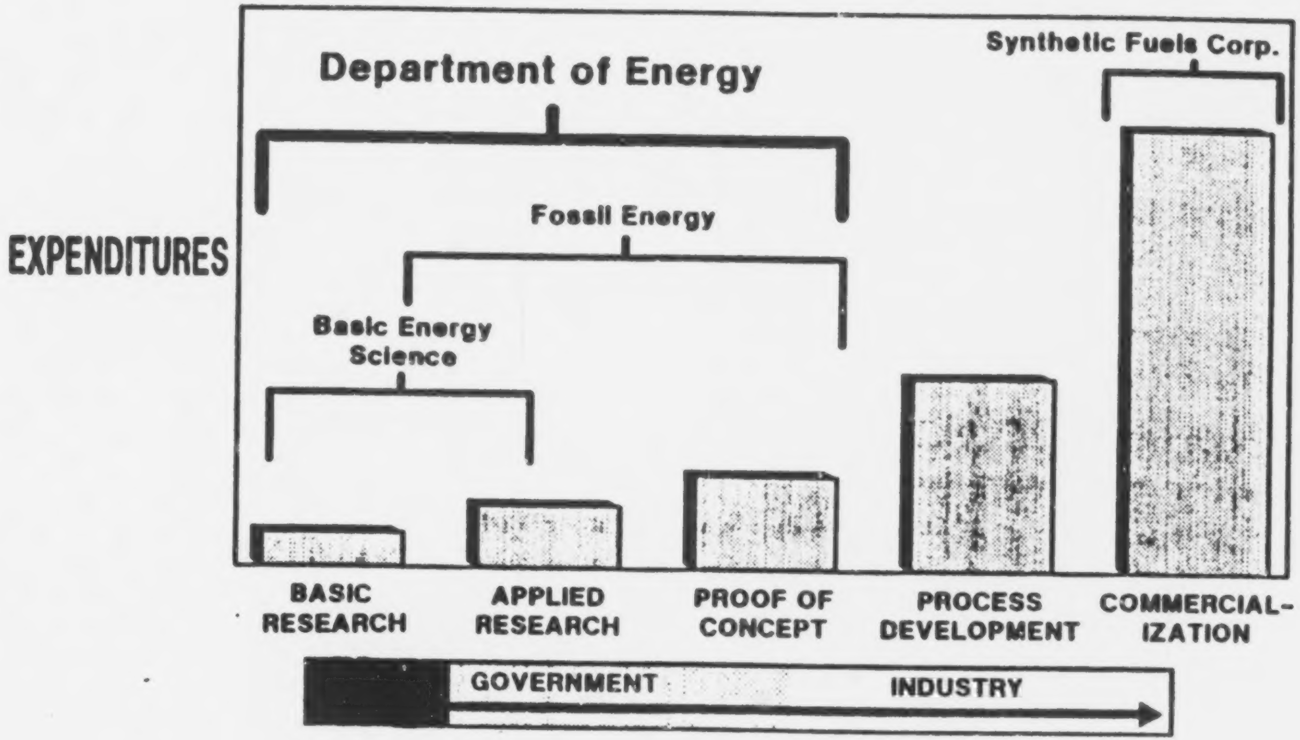
Underground Coal Gasification - "Proof of concept", when applied to Underground Coal Gasification technology development, is a broader term then the generally used engineering terms such as "bench scale", "PDU", and "pilot scale", and could encompass any or all of them. In UCG, we are currently developing individual components of the conceived process: site characterization capability, linking capability, process control capability, etc. The "proof of concept" in UCG would be the combination of all these elements into a field test of one near commercial size module. For in situ technologies such as UCG, field testing is for the most part essential at the "proof of concept" development stage because of the problems of simulating the complex geophysics and geochemistry associated with these technologies. The pilot scale operation would contain several modules, time sequenced to provide a steady flow of gas with a relatively uniform composition.

Unconventional Gas Recovery - In the area of Unconventional Gas Recovery the "proof of concept" stage is the level of development where the technology knowledge and risks are substantiated sufficiently to permit decision making by private firms. This stage is conducted in the field at representative reservoirs because of the impracticality of simulating in situ conditions in the lab.

Enhanced Oil Recovery - It is difficult to identify a single facility as "proof of concept" size in Enhanced Oil Recovery operations. This is due to the non-uniform nature of petroleum reservoirs and applicable recovery technologies. In general, however, "proof of concept" can be obtained through experiments involving one or more wells under actual field conditions. Such an experiment would be fully instrumented and would have to run as long as process requirements need to be satisfied. This proof of concept test would resolve specific problems which will determine the technical and environmental feasibility of the process. Information collected would allow evaluation of scaling factors and lead to development of preliminary economic projections.

Oil Shale - "Proof of concept", as applied to Oil Shale, refers to research that provides sufficient data to reduce the marketplace risks associated with industry decisions to proceed with proprietary development of specific technical concepts. Thus, it does not include pilot plant or larger-scale development of specific technical approaches such as might be patentable by industry, but does include laboratory bench-scale research to evaluate the technical merits of new ideas, that, where promise is shown, may be extended to generic process development unit (PDU) hardware for further evaluation. The exact scale of hardware or related tests needed will be dependent on the concept being tested, but generally would not approach the one ton per hour shale processing level that typically characterizes the smallest pilot plant facility for surface processes. In situ technologies require field testing that is scaled commensurate with the particular technology. In special instances, where production of large amounts of representative spent shales and other waste streams for reasonable-scale environmental research on field disposal plots and control procedures is an objective, relatively large generic test facilities may be required.

# TECHNOLOGY DEVELOPMENT PATH



## GENERAL

Question #9: What is your assessment of the time frame required for commercialization of the various synthetic fuels technologies, not counting those plants involved in transactions with the Synthetic Fuels Corporation?

Answer: It is not possible to predict with any precision when emerging technologies will, if ever, reach the commercialization stage. There are just too many variables that affect a company's decision as to when to introduce or take advantage of a new process or technology. In addition, many of the technologies cover a range of options, some of which will emerge earlier than others. For example, advanced oil shale and liquefaction technologies cover a menu of approaches any one of which may be a winner, or loser.

We are, however, able to roughly estimate dates of commercial availability, i.e., the time at which suppliers would accept an order with standard equipment warranty, if our R&D goals are met. General Question #11 lists all Fossil Energy technologies that should be commercially available in the near future. The following is a discussion of the commercial availability of technologies in the areas of Coal Liquefaction, Underground Coal Gasification, Surface Coal Gasification and Oil Shale.

Coal Liquefaction - Coal Liquefaction technology development has progressed to the large pilot plant scale for two direct liquefaction processes (H-Coal and EDS) and these processes are available for commercial license. Indirect liquefaction technology is available commercially for methanol synthesis and for Fischer-Tropsch synthesis (based on South African experience). However, the risk of such pioneer U.S. plant construction and the costs estimated for the products (which are higher than world oil price) are blocking early commercialization. In the next 10 to 20 years it is likely that supply and economic uncertainties in petroleum supplies may produce different market signals and provide a basis for commercial production of liquid fuels from domestic coal resources. Improved process technology, which is resulting from the Federally-supported R&D to build the coal liquefaction data base, will assure that the commercial need can be met with sound and modern technology.

Underground Coal Gasification - The commercialization of Underground Coal Gasification is heavily dependent on the target coal being developed and the availability of other energy resources in the area. From a technical standpoint, development of UCG in subbituminous coals could be one or two field tests from commercialization. In bituminous coals the technology is much more primitive, and needs at least a decade of further development to bring it even with the technology for subbituminous coals, if possible at all in highly swelling coals. In general, the economics of UCG is very favorable when compared with surface gasficiation, but cannot readily compete with natural gas if a nearby supply is available.

Surface Coal Gasification - Surface Coal Gasification technology is comparatively mature. Industry has taken significant strides within the last year to advance commercial gasification technology. In addition to several smaller, on-site gasifiers, four large commercial-scale gasifier concepts are now operating or are in the final stages of construction in the U.S.:

- Fourteen 1000-ton per day Lurgi fixed-bed gasifiers at the Great Plains Coal Gasification Plant under construction in North Dakota (12 of which will operate during full production with two kept on standby);

- Four 900-1000 ton per day Texaco entrained bed gasifiers, two of which are now in operation at the Tennessee Eastman coal-to-methanol facility in Kingsport, Tenn., and two which are being installed at the Cool Water gasification/combined cycle plant under construction at Daggett, Calif.;

- A 600-ton per day KilnGas horizontal rotating gasifier now in startup at the Wood-River Power Station near Alton, Illinois; and

- An 800-ton per day Dowsyn entrained bed gasifier now in operation at Dow Chemical Company's demonstration unit in Louisiana.

Oil Shale - The question is best answered in terms of time required for various stages of development, from processes with which we are most familiar. For example, Chevron has estimated the time frame from start of construction of their surface retort semi-works plant (following earlier pilot plant tests and engineering design) through construction and startup of their first 9,000 bbl/day commercial size unit to be five years. Paraho utilized about seven years in pilot and semi-works plant testing and development of a surface retort process, plus about two years for detailed engineering design of a commercial facility, spread over a 12-year total period. Paraho's process in particular drew upon extensive prior government and industrial R&D that had occurred sporadically over the preceding

30 years. Union Oil Company's intensive and sustained effort to complete final engineering design and construct a single commercial-scale prototype surface retort of 10,000 bbl/day capacity have lasted from 1979 to the present, with shakedown testing now underway. Original pilot plant/semi-works development began in the early 1950s and continued development has proceeded sporadically over the intervening years. Each of the in situ processes of Occidental and Geokinetics required about eight years to proceed from initial small pilot testing through full-scale "commercial" prototype tests (not equivalent to a commercial-demonstration facility with sustained production such as prepared for the Union or Chevron facilities ).

In all of these instances, environmental baseline studies have proceeded in parallel with technology development. Future developers of Federal land without present leases would have to add time as required by leasing regulations for baseline studies in addition to engineering design and construction, even if using licenses to present technology.

None of the preceding time tables include prior industry bench-scale research that must have preceded pilot plant development, as such information is insufficiently available. However, based on what is known including Federal research, it is probable that any specific oil shale process was backed by laboratory-"proof of concept" research on that process of five to ten years.

Most present development plans, of which we are aware, envisage some seven to ten years from initial commercial-scale unit operation to commercial production in the 50 to 100 thousand barrels/day range.

## GENERAL

Question #10: In areas relating to direct combustion of coal, please describe the relative cost of the various alternative technologies being investigated, from coal cleaning through modified combustion techniques, both in terms of ultimate development cost and cost of the systems to the user. Please also delineate the costs of enhanced oil recovery techniques and the costs of developing unconventional gas sources on the same basis. Also show costs for existing technologies.

Answer: Direct Combustion of Coal - An important point to note when comparing estimates of development costs and user costs for various technologies is that the uncertainty involved in the cost estimates often decreases as the technology moves along the technology development path. This is especially important with the technologies related to the direct combustion of coal. These technologies differ considerably in the degree to which they have been developed and, as a result, the associated levels of uncertainty are also different.

The following two attachments provide information relevant to the costs and the expected advantages of various technologies related to coal combustion:

Attachment I (Table 1 and 2). These tables show cost information developed by Fossil Energy for various technologies being investigated. It should be noted that projects in an advanced state of development (i.e., Cool Water, TVA/AFB) are likely to be more accurate than those which are less technologically mature.

Attachment II (Table, notes and references). The table shows the estimated range of costs for commercially available coal (Row I) and four levels of advanced coal cleaning sytems. The ash and sulfur content (range and average) for the cleaned product is shown in the first four columns. The estimated cost of the cleaned coal and the portion of the cost attributed to processing costs only are shown in the columns marked "cost".

Enhanced Oil Recovery - The range of Enhanced Oil Recovery costs for each major EOR technique are shown below in mid-1980 dollars.

| Technique | Total Developer Costs in, $/Barrel |
|---|---|
| Polymer Waterflood | 22-46 |
| Micellar Polymer Flooding | 35-46 |
| Carbon Dioxide Injection | 26-39 |
| Steam Drive | 21-35 |
| In Situ Combustion | 25-36 |

Unconventional Gas Recovery - A recent study of the comparative economics of conventional, deep and unconventional gas showed that as long as conventional and high productivity deep gas prospects were plentiful, unconventional gas was at a relative economic disadvantage. However, as finding costs for conventional and deep gas increase, because of smaller remaining fields and higher rations of dry holes, unconventional gas can be attractive, particularly under incentive gas prices.

In the longer term, unconventional gas will need to be competing with synthetic fuels and imported gas. Here, the relative economics make unconventional gas (except geopressured methane) attractive,particularly with advances in geological understanding and well stimulation technology.

Once means by which to evaluate the economic attractiveness of unconventional gas is to compare it with synthetic fuels by using the investment costs per daily barrel of capacity, a common measure used in the manufacturing and synthetic fuels industries.

While natural resources generally have declining rather than constant production, thus making comparisons with synthetic plants imprecise, adjustments have been made in the calculations to provide gas production rates similar to a synfuels plant. Such an analysis shows the following adjusted investment costs per barrel of daily capacity in 1982 dollars.

| Unconventional Gas Resource | Investment (1982 $ per Daily Barrel) (Life of Project) |
|---|---|
| o Tight Gas | 30,000 - 45,000 |
| o Devonian Shale | 35,000 - 50,000 |
| o Coalbed Methane | 40,000 - 80,000 |
| o Geopressured Aquifers | 60,000 -160,000 |

As a point of reference, the great bulk of the large scale synthetic fuel projects (e.g., Colony Shale Oil, Canadian Alsands, Alaskan Natural Gas Pipeline, Breckenridge coal liquefaction) all appear to cost about $100,000 per daily barrel of capacity, in 1982 dollars.

In all of the examples cited above, only the cost of production has been addressed. The cost to the ultimate user is difficult to calculate since that cost is dependent upon so many unknown variables such as distribution costs, refining costs, etc. No attempt has been made by Fossil Energy to quantify these additional costs.

TABLE 1

| Technology | Investment to Date ($ Millions) | | | Current Status | Future RD&D Requirements | | | Estimated Earliest Date of Commercial Availability[3] |
|---|---|---|---|---|---|---|---|---|
| | | | | | Major Technical Needs | Estimated Cost to Complete ($ Millions) | | |
| | Private Sector | Government | Total | | | Government[2] | Private Sector | |
| Advanced PC - Steam | --- | --- | --- | Integrated Systems in Operation | Prove Availability | ----- | --- | Early 1990's |
| Atmospheric Fluidized Bed | 50 | 350 | 400 | Pilot Plant in Operation<br>Demonstration Plant Pending | Operational Data | 30 | 170[4] | Early 1990's |
| Pressurized Fluidized Bed | 75 | 175 | 250 | Entering Pilot Scale Operation | System Integration Data<br>Turbine/Cleanup System Performance Data | 20 | 250[5] | Mid 1990's |
| Gasifier/Gas Turbine Combined Cycle | 300[1] | 100[1] | 300 | Component Scale Pioneer Plant (Cool Water) | System Integration and Reliability<br>Component Performance | ----- | 325[6] | Mid 1990's |
| Gasifier/Fuel Cell Combined Cycle | 200[1] | 200[1] | 400 | Advanced Laboratory | Fuel Cell Development and Performance<br>Capital Cost<br>Component Performance | 50-150 | 100-200 | Late 1990's |
| MHD | 50 | 450 | 500 | Advanced Laboratory | Channel, Coal Combustor Performance<br>Seed Regeneration, High Temperature Heat Exchanger | 108[7] | 72[7] | 2010+ |

1/ Not including gasifier development costs.
2/ Government cost for technology base research in support of private sector development and commercialization.
3/ Time at which supplier would accept an order with standard equipment warranty.
4/ 200 MW demonstration facility (TVA).
5/ Private sector demonstration plant.
6/ Estimate for Cool Water Plant.
7/ Preliminary estimates for the cost of completing the proof of concept phase.

TABLE 2

| TECHNOLOGY | RELATIVE* PERFORMANCE GOALS | | | | ESTIMATED PERIOD FOR COMMERCIAL INTRODUCTION | QUALITATIVE FACTORS' | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Minimum Emissions Reduction | | Efficiency Improvement | Reduction in COE | | Novelty/ Complexity | Estimated Relative Probability of Achieving Performance Goals | Estimated Relative Flexibility in Terms of Modularity | Estimated Relative Potential for Significant Evolutionary Improvement |
| | $SO_2$ | $NO_x$ | | | | | | | |
| Advanced PC-Steam[1] | 14% | 14% | 17% | 7% to 10% | Early 1990's | Low | High | Low | Low |
| Atmospheric Fluidized Bed[1,2] | 2% to 4% | 50% to 57% | 2% to 5% | 10% to 15% | Early 1990's | Low | Relatively High | Moderate | Low to Moderate |
| Pressurized Fluidized Bed[1,3,4] | 0% to 17% | 55% to 58% | 9% to 20% | -30% to +17% | Mid 1990's | Moderate | Moderate;<br>Low for More Optimistic Values | Moderate | Moderate |
| Gasifier/Turbine Combined Cycle - Current Turbine Technology[1,3] | 0% to 12% | 0% to 12% | 0% to 12% | -30% to +8% | Mid 1990's | Moderate | Relatively Low for More Optimistic Goals | Moderate | High |
| Gasifier/Turbine Combined Cycle - Advanced Turbine Technology[3] | 14% to 20% | 14% to 20% | 10% to 24% | 10% to 18% | Late 1990's | Moderate to High | Moderate pending successful development of "current turbine" technology | Moderate | Low to Moderate |
| Gasifier Fuel Cell Combined Cycle - Advanced Fuel Cell[1,5] | 29% to 38% | Negligible Emissions | 35% to 45% | 0% to 20% | Late 1990's | High | Low | Moderate | Low to Moderate |
| MHD - Early Commercial[1,6,7] | 10% to 30% | 10% to 30% | 10% to 30% | 2% to 30% | 2010+ | High | Low | Low | High |
| MHD - Advanced[7] | 30% to 50% | 30% to 50% | 25% to 50% | 17% to 30% | 2020+ | High | Low pending successful development of "early commercial" technology | Low | Low |

* Technical and economic performance goals are referenced to a conventional PC plant with wet limestone FGD.

Emissions Reduction - Percentage reduction in gaseous emissions relative to reference plant. All plants subject to the 1979 New Source Performance Standards (NSPS). Advanced technologies show a reduction in $SO_2$ and $NO_x$ emissions to the degree that load demand is met with a higher efficiency and correspondingly lower total fuel input than that of the reference plant. In addition, several of the advanced technologies have an inherent reduction in emissions. All technologies are capable of achieving further emissions reductions with varying penalties in efficiency and/or COE.

Efficiency Improvement - Percentage increase in average annual efficiency over the corresponding value for the reference plant.

Reduction in Cost of Electricity (COE) - Percentage reduction in single plant levelized COE relative to the reference plant. Because the technologies have different ratios of capital cost to efficiency, their relative values of COE vary with the relative values assumed for fuel cost, capital cost, and the economic cost of capital to the utility. COE ratios were calculated under three sets of parameters; a base case and two cases chosen to reflect estimated bounding values these parameters might assume. The spread of values tabulated reflect in part the changes caused by the above variations in economic assumptions. Additional spread is due to the differing cost and performance estimates where more than one reference study or configuration was used. These entries do not reflect inherent uncertainties in projecting costs of technologies in R&D. These uncertainties are qualitatively reflected in the column "Estimated Relative Probability of Achieving Performance Goals." Negative values may not preclude systems desirability due to other beneficial characteristics.

Estimated Period for Commercial Introduction - Estimates based upon current (1983) R&D activities. These dates are dependent upon both the level of future R&D and the degree to which the R&D activities are successful.

Novelty/Complexity - Based upon the number and technical maturity of critical system components.

Probability of Achieving Performance Goals - Qualitative estimate of the probability that the performance goals enumerated in the preceding columns can actually be realized. Judgment is based primarily on the number and current technical maturity of critical system components. The largest uncertainty is in the actual cost which would be realized in a mature plant achieving the specified technical performance goals.

Flexibility in Terms of Modularity - From both technical and economic considerations, the ability of a technology to provide acceptable performance with small unit sizes, modularity, can be expected to provide a significant measure of merit. Entry represents a judgment of the degree to which a technology is expected to offer such flexibility.

Potential for Significant Evolutionary Improvement - Judgment as to the degree that successful achievement of the performance goals would provide a basis for modified or advanced configurations offering further improvement.

| CLEANING TECHNIQUE | POTENTIAL FUEL QUALITY RANGE ASH% | RANGE SULFUR% | AVERAGE ASH% | AVERAGE SULFUR% P | AVERAGE SULFUR% O | % | ESTIMATED COSTS COAL ($/MMBtu) | CAPITAL ($/MMBtu/Hr) | O&M ($/MMBtu) | PRODUCT ($/MMBtu) | PROCESSING ($/MMBtu) | APPLICATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I NONE | 8-40 | 5-10 | 20 | 1.9 | 1.1 | -- | 1.20 [1]<br>2.10 | -- | -- | -- | -- | Coal Designed Electric Utility |
| II Commercially Available (14 Mesh x 0) Gravity, Heavy Media, Flotation | 6-18 | 3-5 | 10 | 0.9 | 1.1 | 95 [2]<br>90 | 1.20<br>2.10 | 300 [3]<br>1400 | 0.13<br>0.18 | 1.43<br>2.57 | 0.23<br>0.47 | Coal Designed Utility<br>Oil Designed Utility & Industrial Boilers<br>Blast Furnace |
| III Limited Physical (200 Mesh x 0) HGMS, Flotation, True Heavy Liquids, Agglomeration | 1.5-8 | 2-4 | 4 | 0.4 | 1.1 | 95<br>90 | 1.20<br>2.10 | 1420 [2]<br>1920 [4] | 0.26<br>0.38 | 1.58<br>2.79 | 0.38<br>0.69 | Oil Designed Utility and Industrial Boilers<br>New Industrial Boilers and Heaters |
| IV Extensive Physical (15 Microns x 0) HGMS, THL, Flotation, Agglomeration | .2-2 | 16-2.1 | 0.5 | 0.1 | 1.1 | 95<br>90 | 1.20<br>2.10 | 1850<br>2400 | 0.30<br>0.35 [5] | 1.64<br>2.78 | 0.43<br>0.68 | Oil Designed Utility & Industrial Boilers<br>Gas Designed Utility & Industrial Boilers<br>Industrial Process Heaters/Boilers<br>New Industrial Heaters Boilers |
| V Physical + Chemical | .95-1.1 | .1-.6 | 0.8 | 0.1 | 0.3 | 80<br>70 | 1.20<br>2.10 | 10,000 [6]<br>20,000 | 0.63<br>0.75 | 2.37<br>4.22 | 1.17<br>2.20 | Gas Turbines & Diesel Engines<br>Home & Commercial Heating<br>New Capacity, Electric Utility |

FIGURE II

## NOTES AND REFERENCES

## FIGURE II

1) Assumed coal price of a 2-3% sulfur coal: worst case $2.10/MM Btu, best case $1.20/MM Btu. (FUEL WEEK, 1982)

2) An Engineering/Economic Analysis of the Coal-Pyrite Flotation Process, Hoffman/Holt 1981, DOE/PC/20149-1; EPA, 1978 (Assume 0.34 capacity factor: 220 days/yr, 13 1/2 hrs/day).

3) A. W. Deurbrouck, Private Communication; TVA - Cost Figures for Paradise Coal Cleaning Plant

4) Otisca Industries, Limited., True Heavy Liquid Cyclone Cost Estimate, 1982

5) Otisca Industries, Limited, Otisca "T" Process Economics, 1982

6) "Technical and Economic Study of Chemical Beneficiation Process", ESCOE, March 1983

   - Assume: 95-99% ash removal for coals ranging from 5-11% ash content (output of conventional technology); 200 days/yr operation.

## GENERAL

Question #11: On an overall basis in fossil energy please describe for the Committee (from the earliest to the latest) those technologies which will be commercialized, assuming successful research and development efforts by the government and industry. In this discussion please indicate the time frame in which this commercialization might occur.

Answer: It is not possible to predict with any precision when emerging technologies will, if ever, reach the commercialization stage. There are just too many variables that affect a company's decision as to when to introduce or take advantage of a new process or technology. In addition, many of the technologies cover a range of options, some of which will emerge earlier than others. For example, advanced oil shale and liquefaction technologies cover a menu of approaches any one of which may be a winner, or loser.

We are, however, able to roughly estimate dates of commercial availability, i.e., the time at which suppliers would accept an order with standard equipment warranty, if our R&D goals are met.

The following table lists the technologies being pursued by Fossil Energy and the earliest date of their commercial availability as we perceive it today. Where multi-options are being pursued, the earliest available date refers to the option that appears nearest to fruition.

| Technology | Earliest Avail. Date |
|---|---|
| Advanced Physical Coal Preparation | Late 1980s |
| Coal Water Slurry | Late 1980s |
| Small AFB/ADV | By 1990 |

| Technology | Earliest Avail. Date |
|---|---|
| Advanced Combustion Technology | By 1990 |
| Chemical Coal Cleaning | Early 1990s |
| Underground Coal Gasification | Early 1990s |
| Limestone Injected Modified Burner (An EPA development) | Early 1990s |
| AFB Utility Retrofit | Early 1990s |
| Tar Sands (lenticular) | Early 1990s |
| Advanced $SO_x/NO_x$ Cleanup | Early 1990s |
| PFB | Mid 1990s |
| Advanced Oil Shale Technologies | Mid 1990s |
| Advanced EOR (chemical, microbial) | Mid 1990s |
| Western Tight Gas Sands | Mid 1990s |
| Eastern Gas Shales | Mid 1990s |
| Advanced Coal Liquefaction Technologies | Mid 1990s |
| Gasifier/Fuel Cell Combined Cycle | Late 1990s |
| Coal Fired Turbines/Diesels | Late 1990s/Early 2000s |
| MHD | After 2010 |
| Gas Hydrates | After 2010 |

## GENERAL

Question #12: To what extent and in what time frame do you expect coal based fuels to penetrate markets currently supplied by liquid fuels?

Answer: The time frame and the extent to which coal based fuels will penetrate markets currently supplied by liquid fuels is highly dependent upon the price and availability of natural petroleum resources. For example, at the present time, the technology is available to make liquid and gaseous fuels from coal that are compatible with fuels made from natural resources, but, they are expensive. According to a technical report in support of the National Energy Policy Plan - coal-based synthetic liquids will begin to penetrate the market place in 1995 with the sale of 0.1 quads of coal-based liquids, and rise to between 0.9 to 1.5 quads in 2010. This assumes a world price of oil of $30.50 (1982 dollars) in 1985 and from $54.60 to $111.40 (1982 dollars) in 2010.

Fossil Energy R&D programs are also focused on improving the efficiency of producing synthetic fuels from coal. Success in these efforts could effect the penetration rate outlined above beyond the year 2000.

In another area, Fossil Energy is devoting R&D efforts to develop new coal fuel forms, i.e., coal liquid slurries and ultra fine coal that is virtually sulfur and ash free, which can be substituted for natural liquid fuels. The first market penetration of coal water slurries will be in the late 1980's as a fuel for coal capable boilers that are now burning oil.

Finally, Fossil Energy is studying concepts such as advanced fluidized bed combustors that could potentially be economically and environmentally attractive at small scale, and thus substitute for liquids in certain applications.

The potential for all of these coal-based fuels is very large, but realization of that potential is heavily dependent upon the price and availability of natural petroleum products. It is not possible, at this time, to measure the rate of market penetration of the different fuel forms because of the many variables that affect the ultimate decisions of individual consumers.

## GENERAL

Question #13: Please explain what constitutes an "affordable capability" to reduce emissions from acid rain precursors, and when this capability can be achieved.

Answer: "Affordable capability" as it relates to acid rain control refers to technologies that have the potential to reduce acid rain precursor emissions from older coal fired plants that are not required to conform to the requirements of New Source Performance Standards (NSPS). These technologies would achieve modest, but adequate, reductions in emissions (compared to NSPS), and could be retrofitted to existing coal fired plants at substantially lower cost than the cost of flue gas cleaning systems for compliance with NSPS.

It is anticipated that these retrofit technologies would have one or more of the following characteristics:

- o 50 percent (minimum) $SO_2$ control.
- o 50 percent (minimum) $NO_x$ control either in the cleanup process itself or attained through the use of combustion modification control.
- o Maximum cost (levelized basis) of $500/ton of $SO_2$ removed as compared to $600-1000/ton for limestone scrubber technology.
- o Production of either a salable by-product or a nonhazardous dry waste suitable for disposal in a landfill.

DOE has a new initiative of $5.2 million in the FY 1985 budget request to accelerate this work. Given the leadtimes associated with R&D projects reaching commercialization, a rough estimate of commercial availability of these technologies is the early 1990s.

## CONTROL TECHNOLOGY AND COAL PREPARATION

Question #1: Please describe your proposed activities in developing a coal cleaning program with the Electric Power Research Institute. In addition to adding circuits at their current facility, could the program be used to provide any kind of slurry testing or combustion testing of the cleaned coals? Would EPRI be interested in such activity?

Answer: The specific objective of the joint DOE/EPRI coal cleaning technology program is to select, fabricate and test advanced fine coal cleaning technologies (at the EPRI Coal Cleaning Test Facility) which offer significantly improved sulfur and ash rejection and reduced BTU loss with improved economics.

The extensive application of improved coal cleaning technology has the potential of providing the most cost effective means of reducing sulfur dioxide emissions from existing coal fired power plants. Several significant benefits could accrue as the result of extensive application of improved coal cleaning systems. In addition to $SO_2$ reductions, each of the additional benefits listed below have the potential of helping offset the costs of cleaning the coal:

- reduced transportation costs by 10% per million btu delivered*
- improved power plant availability and reliability due to reduced ash levels
- more exact quality control on power plant fuel
- reduced waste management costs by 85%*
- reduced pulverizing cost by 10%*
- reduced Flue Gas Cleanup capacity (if required) by 60%*

* Assumes that coal has 12% ash, 2% pyritic sulfur and 1% organic matter initially

The joint program will begin in FY 1984. It is anticipated that a competitive procurement will be issued by the Pittsburgh Energy Technology Center for design, fabrication, installation, and operation of the advanced device(s). Multiple awards are desired. The devices are expected to be in the 1-2 ton per hour size range. With first contract awards in late calendar year 1984, the first installation could possibly begin at the Coal Cleaning Test Facility in calendar year 1985.

This joint activity provides an excellent opportunity for both DOE and EPRI to better meet their program objectives in the coal cleaning area in the most cost effective manner. The management of both strongly endorse these efforts.

At the present time, plans have not been finalized for testing of the cleaned coal. However, projecting the impact of the beneficiated coal on boiler performance is important to both the DOE and EPRI programs. Further discussions between DOE and EPRI will be held regarding future testing.

CONTROL TECHNOLOGY AND COAL PREPARATION

Question #2: What activity has been done to date, and what has been planned for FY 1985 for the so-called "gravimelt" process? Are there any plans for a larger unit?

Answer: The Department of Energy is supporting research and development projects in the area of chemical desulfurization of coal, one of which is the TRW "gravimelt" process. The technology is a method for near-complete desulfurization and demineralization of coal by a series of two leaching operations. The basic process can be viewed as follows:

> Crushed coal (smaller than 14-mesh) is treated with molten alkali metal hydroxides (NaOH/KOH at 350-380°C) to remove organic and pyritic sulfur, removal of the molten media from the coal, washing with water to remove residual media from the coal and washing with dilute acid to remove mineral matter.

A simplified flow scheme is shown in Figure 1.

The complete process requires regeneration of both the alkali metal hydroxides and the neutralization of the dilute acid wash streams.

"Gravimelt" technology was first introduced to DOE by TRW in 1980. It has demonstrated an ability to produce a low ash, high BTU, compliance coal (with respect to the EPA NSPS). Additionally, a recent independent economic study found this chemical coal cleaning technology very cost competitive with oil and gas on a cost/MM BTU basis. The technology is now at a bench-scale stage of development requiring overall scale-up of the process sections for continued technology refinement.

As Figure 1 indicates, the process consists of primarily three sections: reactor, washing, and regeneration. During the past three years of work, substantial progress has been made in all aspects of the project. Significant accomplishments include:

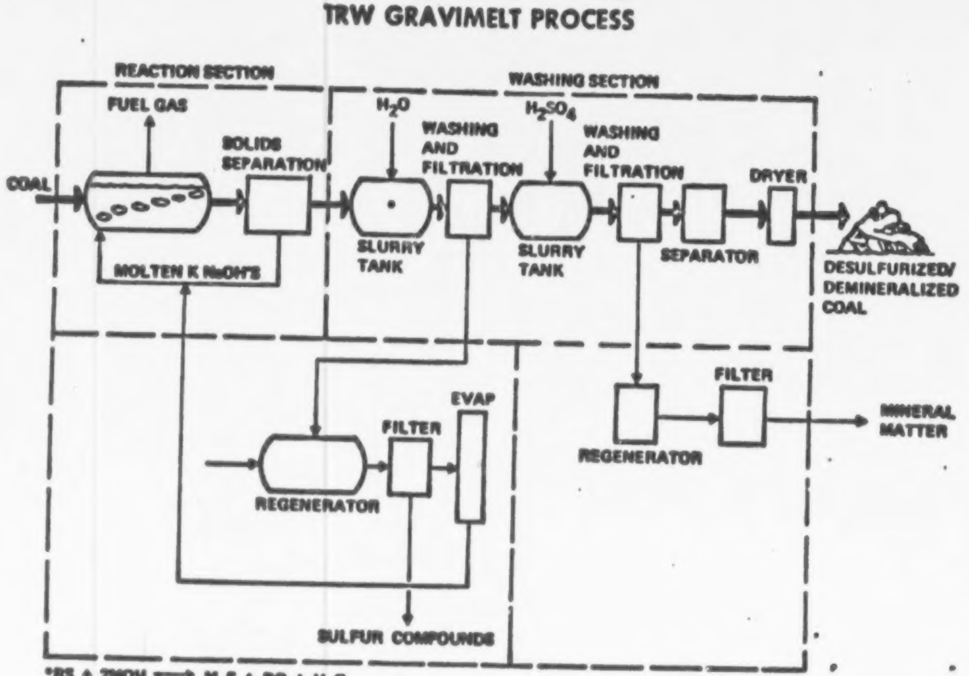
- Reproducible removal of 90 percent or more of a coal's total sulfur.
- Reproducible removal of greater than 90 percent of a coal's total ash (sometimes as high as 99 percent ash removal).
- Demonstration of the ability to feed coal into a molten caustic bath and retrieve it from the bath in a continuous laboratory-scale operation.
- Demonstration of the ability to wash the coal to free unused and spent caustic.
- Demonstration of the ability to acid wash the caustic-treated and water-washed coal to produce the final coal product with greater than 90 percent ash removal.

However, further information is required regarding caustic recovery efficiency, caustic to coal ratio, coal residence time and so on prior to further scale up of the technology.

The current effort, which will continue until August 1986, is a continuation of the bench-scale development of the modularized unit sections, i.e., reactor, regeneration, and washing and filtering. To develop each section required for operation, it is necessary to test at laboratory and bench-scale: 1) steps involved in the regeneration of caustic, including the conversion of coal-derived sulfur compounds to the acid needed in the wash section, 2) separation of processed coal and other solid materials from the fused caustic using subscale commercial-type filtration units, 3) washing caustic and acid from the solids in a multi-stage, counter-current mode to control water usage, and 4) the regeneration of caustic and wash water streams for recycle by evaporation, liming, or other suitable treatment of the caustic and acid washes. In addition, an engineering design and construction of a small (20 pound per hour) "Gravimelt" coal processing circuit for continuous operation and testing of its sections is included.

Current planning includes further refinement of the fused-salt process which will eventually require a scale-up to a proof-of-concept level, i.e., greater than 500 pounds per hour. This will entail a detailed engineering design (based on results from current efforts), construction and operation.

The FY 1985 budget request includes funding for a preliminary design of a PDU utilizing an existing facility with cost sharing. The decision to proceed to final design, construction and operation of a unit will depend on the results of the evaluation of the process and the completion of the preliminary design in FY 1986.


TRW GRAVIMELT PROCESS
REACTION SECTION
WASHING SECTION
FUEL GAS
COAL
SOLIDS SEPARATION
MOLTEN K NaOH'S
H2O
WASHING AND FILTRATION
SLURRY TANK
H2SO4
WASHING AND FILTRATION
SLURRY TANK
SEPARATOR
DRYER
DESULFURIZED/ DEMINERALIZED COAL
REGENERATOR
FILTER
EVAP
SULFUR COMPOUNDS
REGENERATOR
FILTER
MINERAL MATTER

*$RS + 2MOH \rightleftharpoons M_2S + RO + H_2O$

$mFeS_2 + nMOH \rightleftharpoons Fe_xO_y + nM_2S + nH_2O$

Figure 1. Gravimelt Process Flow Scheme

## CONTROL TECHNOLOGY AND COAL PREPARATION

Question #3: Please provide estimates of the cost for the clean fuels being developed and compare them to the cost of the fuels that they would replace. Please also delineate the applications envisioned for these fuels, and when you expect the applications to be developed.

Answer: Estimates for the cost of the clean fuels being developed through the Federal Coal Preparation R&D program and a cost comparison to the fuels they would replace are provided as follows. Also, applications envisioned for these fuels and an estimated timeframe for earliest market introduction is included. It should be noted that the cost estimates for the cleaned fuels are DOE/FE rough estimates and that the confidence in the estimates is greater for the near term technologies (e.g., advanced physical cleaning) than the longer term technologies (e.g., chemical coal cleaning).

| APPLICATIONS/MARKETS | QUALITY<br>COMPETING<br>Range % 3<br>S | <br><br><br>Ash | FUEL<br>Average % 2<br>S | <br><br>Ash | PRICE<br>COMPETING<br>$/MMBTU<br>Range | <br>FUEL<br>Delivered<br>Average | ESTIMATED PRICE OF CLEANED FUELS BEING DEVELOPED$/MMBTU<br>Range | <br>Average | MARKET (MAXIMUM) OIL DISPLACEMENT<br>1985 | <br>1990 | <br>2000 | MARKET (MAXIMUM, GAS DISPLACEMENT<br>1985 | <br>1990 | <br>2000 | MARKET INTR. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal Designed Electric Utility | - | - | - | - | $1.10-2.35[1)] | $1.90 | | | - | - | - | - | - | - | |
| Coal Designed Util now using oil/gas | 0.7<br>3.5 | 0.01<br>0.5 | .75 | 0.1 | 4.28 - 4.92 | 4.70 | 1.43 - $2.57 | | 383 | 383 | 383 | 10 | 10 | 10 | 1987 |
| Oil Designed Util & Large Ind Blrs | 0.7<br>3.5 | 0.01<br>0.5 | .75 | 0.1 | 4.28 - 4.92 | 4.70 | 1.58 - 2.79 | | - | 1200 | 1200 | 0 | 0 | 0 | 1987 |
| New CLM Designed Ind Boilers & Htrs | .7<br>3.5 | .01<br>.5 | .5 | .1 | 4.28 - 4.92 | 4.70 | 1.64 - 2.78 | | - | 353 | 625 | - | 737 | 1170 | 1995 |
| Gas Designed Util & Ind Blrs & Oil Des Ind Heaters | 0 | 0 | 0 | 0 | 3.28 - 4.52 | 3.68 | 1.64 - 2.78 | | -4) | 900 | 900 | - | 3000 | 3000 | 1995 |
| Gas Turbines | 0 | 0 | 0 | 0 | 3.28 - 4.52 | 3.68 | | | - | - | 150 | - | - | - | |
| Diesel Engines | 0.05<br>1.0 | trace | .2 | 0 | 7.12 - 7.58 | 7.36 | 2.37 - 4.22 | | 4) | - | 150 | - | - | - | 2005 |
| New Home heating & Comm Heating | 0.05<br>1.0 | trace | .2 | 0 | 7.12 - 7.58 | 7.36 | 2.37 - 4.22 | | | - | 130 | 960 | 370 | 3600 | 2005 |
| New Utility Capacity | NSPS | | NSPS | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | |

[1)] Coal Week, September 1982, Coal Week Fuel Pricing Trend

2) EIA

3) Steam, B&W, 39th Edition

4) Assumed savings in marine and locomotive applications only. Coal Fired cogeneration could increase this number.

FIGURE III

## CONTROL TECHNOLOGY AND COAL PREPARATION

Question #4: What is the current status of coal cleaning technology? What pollutants can be removed from coal and to what degree?

Answer: The majority of coal cleaning research and development in the United States is currently being carried out by the U.S. Department of Energy (DOE), the Tennessee Valley Authority (TVA), and the Electric Power Research Institute (EPRI). The TVA program is concerned primarily with problems as they exist under today's conditions. This includes the important question of how to measure the effects of coal quality on power generating costs in existing plants. The EPRI program places greater emphasis on experimental fine coal, physical cleaning technologies that could lead more promptly to full scale operation, given firm assurance of process feasibility and favorable economics. From the longer range perspective, the DOE is seeking to improve the quality of coal to levels which could provide economic and environmental advantages in the future. This work is directed more towards potential advantages in oil and gas conversions, an $SO_2$ control option, coal slurries, new boiler designs, and, in the long term, direct firing in power conversion equipment.

The essence of coal preparation is the separation of ash forming mineral matter and sulfur from coal. These impurities or unwanted constituents vary widely not only from coal to coal, but even within a particular seam itself. Also, different types respond differently to different techniques for separating the ash and sulfur. Therefore, the specifications on coal cleaning technology performance and economics are very dependent on coal input.

The commercial practice of coal cleaning is currently limited to separation of the impurities based on differences in the specific gravity and mass of coal constituents, i.e., gravity separation processes (jigs, heavy media cyclones, tables, etc.), and the differences in surface properties of the coal and its mineral matter content, i.e., froth flotation. These processes can remove up to 60 percent of the ash and sulfur, depending upon the characteristics of the specific coal at hand, with product yields ranging from 60 to 90 percent, and thermal recoveries of 85 to 98 percent. Typical cleaning costs range from $3-12/ton of feed coal.

Usually, the feed coal is crushed to 2 inches top size, which limits mineral matter (including pyritic sulfur), release and subsequent removal. The crushed coal is then sized by screening into coarse (2 inches by 3/8 inch), intermediate (3/8 inch by 28 mesh), and fine size (28 mesh) streams. These streams are then cleaned with the appropriate equipment, e.g., the 28 mesh stream is commonly processed with froth flotation devices.

Physical cleaning extracts only the coarser forms of mineral matter, including pyritic sulfur, but none of the organic sulfur. The average sulfur content of U.S. coal beds (DOE, RI8118) based on approximately 450 samples is:

| | wt.% |
|---|---|
| Total Sulfur | 3.0 |
| Pyritic Sulfur | 1.9 |
| Organic Sulfur | 1.1 |

## CONTROL TECHNOLOGY AND COAL PREPARATION

Question #5: What industrial or utility interest has there been in substituting the clean coal-based fuels for oil and gas units?

Answer: In the Control Technology and Coal Preparation activity, interest in our clean coal-based fuels program has been enthusiastic from both the utility and industrial sectors development data base. Each year DOE conducts an international symposium on coal slurry combustion. This symposium is designed to disseminate and exchange the latest information on coal slurry mixtures to the world community. Last year the symposium was held in Tampa, Florida and was attended by 750 people.

In 1981, DOE conducted a "Coal Water Fuel Technology Workshop" in Pittsburgh, Pennsylvania to obtain the views of private industry on the areas that required further research. The advice of industry was that DOE should not try to formulate coal slurries, but do basic research. We are following this guidance. Over 50 companies participated in this workshop.

Several private companies are actively engaged in coal water mixture research. Florida Power and Light Company is conducting tests using coal water mixtures on a modified coal oil mixture combustor with the view of converting some of its existing oil fired units to coal water. The Atlantic Research Corporation is constructing facilities to produce coal slurries. Gulf and Western is operating a small pilot plant designed to produce coal water slurries. Other companies engaged in coal slurry preparation are Occcidental Research and Slurry Tech, Inc.

Industry interest in highly cleaned coal slurries is not limited to their use in conventional oil or gas field boilers. Florida Power and Light Co., for example, is considering coal slurry as the feed for pressurized fluidized bed combustors. In addition, DOE with our industrial counterparts are looking at coal slurries as the fuel for advanced heat engine and fuel cell concepts.

CONTROL TECHNOLOGY AND COAL PREPARATION

Question #6: Please review the major programs you have in systems meant for combined $SO_x$, $NO_x$ removal. In this area, what is your estimate of the time necessary to bring these processes to commercial fulfillment if the R&D is successful?

Answer: The major projects currently underway in the area of combined $SO_x/NO_x$ removal are the Electron Beam/Lime Spray Dryer, the Electron Beam/Ammonia Injection process and the Fluidized Bed Copper Oxide process. Shakedown testing of the E-Beam/Spray Dryer proof-of-concept test unit at TVA's Shawnee plant was initiated the week of 2/13/84. Parametric testing will be conducted through July 1984. Equipment procurement for the E-Beam/Ammonia process proof-of-concept test unit at Indianapolis Power and Light's E. W. Stout plant is underway. Construction is scheduled to start this April (1984). The test phase is scheduled to be conducted from 8/84 through 9/85.

Bench scale testing is continuing on the PETC Fluid Bed Copper Oxide process. Simultaneous control of both $NO_x$ and $SO_x$ at the 90 percent level has been demonstrated successfully. However, the sorbent attrition rate is unacceptably high. This is a phenomenon not experienced in the earlier lab scale work using a simulated flue gas. Current emphasis is on the isolation and resolution of the sorbent attrition problem which is a prerequisite to the planned scaleup of the process to the proof-of-concept stage in FY 1985.

Assuming successful completion of the R&D and the willingness of industry to sponsor prototype demonstration plants, commercial offerings of these processes could occur in the early 1990's.

CONTROL TECHNOLOGY AND COAL PREPARATION

Question #7: What work are you specifically doing to develop technology for the retrofitting of existing plants? Is this work for the combined reduction of $SO_x$ and $NO_x$ or is it also involved with only $SO_2$ removal?

Answer: We have not yet started a program to develop retrofit technology. This is a new initiative proposed for FY 1985. Our approach will be to look at both combined $NO_x/SO_x$ processes and $SO_2$ only processes that can be combined with state-of-the-art combustion modification technology for $NO_x$ control, i.e., R&D of combustion modification technology per se will be excluded. The objective of this new initiative will be the development of low cost, retrofittable technology of relatively modest performance for acid rain control. In addition to looking at flue gas desulfurization which can be combined with combustion modification for $NO_x$ control, we will also evaluate combined $NO_x/SO_x$ processes currently being developed for New Source Performance Standards applications. Tradeoff studies will be made to examine issues such as relative costs of treating a part of the gas stream at the 90 percent control level versus treating the full flow at a 50 to 60 percent control level. Assessments will also be made of potential retrofit problems because of system size and complexity.

CONTROL TECHNOLOGY AND COAL PREPARATION

Question #8: What makes a system retrofitable or unretrofitable? Why are the cost requirements different for such systems? In other words, why are low cost systems looked at for retrofitable purposes?

Answer: There is no clear cut demarcation between retrofitable and unretrofitable systems. There is a tradeoff between factors such as cost, performance, system complexity, ease of installation, and real estate requirements. Additionally, many of these factors are site specific. An example of a retrofitable process is the LIMB. It is theoretically a relatively simple process requiring a minimum of space and equipment. However, its performance characteristics make it unsuitable for application to new plants. On the other hand, lime or limestone scrubbers, although capable of meeting New Source Performance Standards (NSPS), are complex, expensive, require many large process vessels (scrubbers, slurry tanks, etc.) and a commensurate amount of space. Although theoretically a scrubber system can be retrofitted to a generic power plant, it is one thing to design a new plant incorporating a scrubber and quite another to shoehorn a scrubber into an existing plant. One of the driving factors to emphasizing low cost for retrofit applications is the potential impact on the rate base. With a new plant, such impacts can be accounted for at the time the plant is designed. This is not the case with existing plants. Furthermore, an existing plant will have a shorter useful lifetime over which the flue gas treatment system can be amortized and depreciated. Therefore, a given system will have a potentially greater impact on the rate base when installed in an existing plant as compared to a new plant. Additionally, because of their low costs, retrofitable processes appear to offer the potential of more pollutant removed per dollar spent at the projected lower percentage pollutant removal levels.

## CONTROL TECHNOLOGY AND COAL PREPARATION

Question #9: Please explain what your competitive procurement for testing of acid rain precursor control technology at the proof-of-concept level will entail. How much money do you have allocated to this procurement? Do you expect to award multiple contracts?

Answer: The proposed competitive procurement will solicit innovative approaches for the control of acid rain precursors with proof-of-concept to be demonstrated through testing on coal fired boiler slipstreams in the 5-10 MWe size range. In view of the current EPA and EPRI activities on LIMB technology, our current plans are to exclude limestone injection into the combustion zone. Two potential approaches are the use of pressure hydrated lime and dry sorbent injection into the duct. The projected funding for this procurement is $5,225,000 in FY 1985 with approximately the same level of funding for the following two fiscal years. This should enable us to award a minimum of three contracts.

## CONTROL TECHNOLOGY AND COAL PREPARATION

Question #10: Why are you reducing the research in gas stream cleanup for pressurized fluidized beds? Is this not a technologically promising area for the near term? Will the technology be applicable to the burning of coal in turbines? What is the penalty in terms of process efficiency for quenching and reheating the gas stream of a PFB or turbine process?

Answer: The Gas Stream Cleanup request for FY 1985 is lower than the FY 1984 budget due to a number of factors. For FY 1984, $1,000,000 was appropriated for hot gas cleanup studies within the Surface Coal Gasification program. This effort reaches fruition in FY 1985 with two hot gas test loops where cleanup devices developed under Control Technology are planned to be part of the test installation; therefore, costs to the Control Technology program are reduced. Use of other test facilities such as NYU are being considered for some upscale testing of gas stream cleanup devices where only piggyback operating costs are anticipated. Other planned PDU and proof-of-concept testing of promising particulate removal devices, which are expensive, are experiencing delays; therefore, the smaller lab testing phases (less expensive) of alkalies and other trace pollutants are being pursued intensively in order to match and catch up with particulate technology which is planned to provide total hot gas cleanup system removal capabilities on a more optimum cost/time track. Minimal effect on the long range goals to be achieved is anticipated due to the delays.

To date, the cleanup research directed to the Pressurized Fluidized Bed (PFB) area has been very promising with a number of competing High Temperature/High Pressure (HTHP) particulate removing techniques having been tested successfully at the PDU level, with some devices tested on actual coal-fired gas streams. Consequently, the particulate systems are considered very near-term technologies. However, alakli removal technologyis not as advanced with several possible candidate techniques selected for lab scale testing in FY 1984.

The PFB removal technology is to a large extent directly applicable to direct coal-fired turbines. However, the combustor must be (off machine) separate to allow installation of contaminant removal devices. Standard gas turbines are close coupled with the integrated combustor which does not allow any space for installing a hot gas cleanup device. The free standing combustor design has ample space for installing the hot gas cleanup device between the combustor and turbine.

Quenching and reheating the gas (large volume) stream for the PFB combined cycle turbine is very severe (out of the question) since the gas stream has no fuel energy value. The penalty in terms of process efficiency for quenching and reheating the gas stream of a PFB turbine process is extremely high. For example, if we use a good heat exchanger (90 percent heat recovery) the system sees a 10 percent decrease in efficiency as a minimum with no consideration of losing the sensible heat of the water vapor in the PFB exhaust which can easily be another 1-2 percent loss. In addition, the pressure of the PFB exhaust gases is lost. Therefore, an AFB can be substituted for the PFB obtaining a higher efficiency.

Gasification combined cycle systems are to some extent a different story, where the quenching can be tolerated since only a small fraction of the hot gas stream is sensible heat. Due to the considerable smaller volume of gaseous fuel involved with the gasification combined cycle application, the penalty in some cases is acceptable (depending on the gasifier/turbine and conventional cleanup system selected) ranging from 2 percent to as high as 5 percent.

## CONTROL TECHNOLOGY AND COAL PREPARATION

Question #11: Is the research on cleanup technology for fuel cell applications also being reduced? If so, why?

Answer: The research on cleanup technology for fuel cell applications is being redirected to emphasize laboratory scale efforts which are less expensive than larger scale devices and, therefore, require less funding. Pollutants other than sulfur, such as alkali, chlorides, soot and ammonia, are being emphasized in these lab scale developments. The larger scale hot desulfurization process unit work is planned for inclusion in the hot gas cleanup test units being funded by FY 1984 Congressional direction under the Surface Coal Gasification program. This planned series of tests are expected to provide operating data and capabilities for the early development of cleanup devices. We believe the FY 1985 budget request for Gas Stream Cleanup is adequate to provide the necessary cleanup systems R&D to support the efforts proposed in FY 1985 for the MCFC program.

## CONTROL TECHNOLOGY AND COAL PREPARATION

Question #12: Your budget justifications (pg. 31) state that there are several removal concepts that have distinct cost and performance advantages with regard to removal of particulate and alkali contaminants from combustor gas streams. Please explain what those concepts are and what those advantages are. The same justification discussed lab scale tests being conducted on actual coal fired combustor systems. Where will these tests be done? After bench scale testing who will do the next stage of development?

Answer: Each removal concept that has been tested through lab scale has received cost estimates based on conceptual design of a final system using the device. Using this data, some devices appear to have cost and performance advantages superior to others; however, each cost estimate used ranging parameters in reaching its conclusion. Therefore, to obtain as realistic a comparison as possible, an ongoing FY 1984 project is putting these competing devices on a comparable basis to establish the relative cost and performance of each system. These results are expected to provide a sound base for selecting those candidate systems for future research and also for eliminating those marginal devices which do not really compete.

For alkalies, only limited lab scale research has been conducted using selected sorbents, with the following two FY 1984 projects scheduled to be conducted:

- Argonne - PFB tests of alkali sorbent (activated bauxite).
- General Electric - PFB tests using a simulated PFB combustor test of alumino-silicate aerosols.

The High Temperature High Pressure Electrostatic Precipitator (HTHP-ESP) has demonstrated excellent particulate removal capability (over 99 percent) at both subpilot scale coal combustor testing (Curtiss-Wright small turbine test rig) and presently under simulated controlled conditions (Denver Research Institute). Combustion Power Corporation has demonstrated a moving granular bed particulate filter on Atmospheric Fluidized Bed (AFB) exhaust for several hundred hours with very good particulate removal capability (over 99 percent). These two devices demonstrate credible performance in achieving New Source Performance Standards (NSPS) within the reasonable future by using two distinct removal technologies. Both devices are anticipated to have long operating lives, consistent particulate removal capability, predictability, and momentary surge capabilities.

Lab scale tests on small AFB combustors are proceeding at Air Pollution Technology Corp., San Diego, California, of a dry plate moving bed granular filter scrubbing device. A slip stream test from a small PFB test unit is being utilized to test an annular vertical granular moving bed at G.E. at their Malta test station. The Westinghouse ceramic cross flow filter has been successfully tested on a small PFB test rig at Argonne National Lab.

The next logical testing step after bench scale is the subpilot scale which will be carried out in a program which is cost shared with private industry. A possible location for future testing is the New York University PFB test facility. Plans are to `piggyback' these test devices onto ongoing, other purpose projects.

Other conceptual particulate removal devices remain promising but have been tested only on simulated hot gas particulate loaded streams.

It is anticipated that the next stage of testing research will be done by the government with industrial cost sharing.

## CONTROL TECHNOLOGY AND COAL PREPARATION

Question #13: The waste management program discusses building upon the waste management data base already developed. Who uses the data base currently, and what is its role in relation to EPA or the states?

Answer: The data base discussed under waste management refers to the fossil fuel cycle waste sampling and characterization effort undertaken by Fossil Energy. The objective is to develop a definitive and authoritative body of data on the chemical and physical characteristics of fossil fuel cycle residues from a variety of conventional and advanced fossil fuel utilization processes, e.g., coal preparation, combustion, flue gas cleanup, conversion systems, etc. At the present time, data on sampling and characterizations of coal burning utilities wastes has been acquired and documented in formal reports. The final form of presenting this information within the attendant data base is being analyzed and researched in-house at METC so as to obtain widespread use and utility in the future by as many interested parties as possible. Compatibility of the data base with data expected from emerging coal utilization technologies wastes is a critical requirement during the formulation of the base project. It is anticipated that final selection of form and content of the Waste Management data base will be made by the end of calender year 1984. Once this data is generated, the proper rationale will be applied and the priority of additional research needs for waste disposal within the required environmental constraints and acceptable costs will be identified and implemented.

The private sector, as well as DOE, EPRI, EPA and other government and institutional organizations will have access to the information.

All groups, especially EPA and EPRI, who have been apprised of the DOE/FE work are extremely interested in the data as it is being generated. The waste management data base already developed has resulted from the completion of a preliminary evaluation of representative coal waste samples from utility sites.

Coal feedstock and all associated waste stream samples were collected from eighteen utility sites representing a cross section of the country. The samples under careful control, were repackaged, coded and subsequently distributed to and analyzed by, commercial and government laboratories as well as a number of DOE/FE Energy Technology Centers.

The Environmental Protection Agency's (EPA) Extraction Procedure (EP) toxicity test for inorganic materials and the American Society of Testing and Materials (ASTM) standard leach test (ASTM D3998) were employed in analyzing the utility waste products. A complete statistical analysis of the data will be made available in a report scheduled for release in late April 1984. The report will be helpful to both state and federal officials regarding legislative proposals concerning these wastes. EPA will also reference such data in their promulgation of environmental regulations.

The FY 1984 and FY 1985 program is focusing on the sampling and characterization of wastes from advanced technologies being developed by Fossil Energy. The existing and developing waste management sampling and characterization data base will (1) assist in defining and addressing waste disposal problems, (2) permit prioritization of R&D, (3) provide the fossil energy users with an awareness of any potential obstacles to greater utilization of fossil fuels and assist them in understanding their respective responsibilities, and (4) assist federal and state agencies in the promulgation of effective and economically acceptable environmental control regulations.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #1: Please explain the decrease in the instrumentation control and diagnostics area. What is the relative importance of the problem of not being able to accurately measure properties of systems utilizing coal? How do these uncertainties affect the engineering of reliable processes?

Answer: The decrease in the Instrumentation, Control and Diagnostics program will be achieved with minimal impact on the current program. Research will be slightly reduced fairly evenly across all activity areas. This will permit strong efforts to be maintained in the following:

- o multiphase flow parameter measurement techniques
- o temperature measurement
- o chemical measurement

Specifically, the decrease in the AR&TD Instrumentation, Control and Diagnostics program will merely extend the time at which new, more accurate and reliable instrumentation will be available for use in coal conversion and utilization systems. Currently available measurement techniques are not sufficiently precise to allow accurate equipment design or control or process parameters. This lack of capability forces over-design to provide an additional margin of safety which consequently increases capital costs.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #2: Your justifications (p. 39) state that the entire AR&TD program is undergoing a peer review. Who is conducting this review? What specifically is the review supposed to do, and when will results be available?

Answer: The peer review of the Advanced Research and Technology Development (AR&TD) program is being conducted by the Office of Program Analysis in DOE's Office of Energy Research. Energy Research has obtained the services of experts from industry, academia, and national laboratories to serve as reviewers.

The purpose of the peer review is to assess the quality of the research undertaken in the AR&TD program; to note gaps or duplications in the program; and to recommend targets for future federal research in this area. For each of the approximately 100 projects being evaluated, the following areas will be evaluated:

- Team quality
- Scientific merit
- Scientific approach
- Productivity
- Probable impact of the project
- Success rating of the project

Overall results of the peer review will help us to correct any deficiencies that now exist and to plan for future research in the program. The last of the three sets of reviews will be completed on February 23. A final report is expected by the end of April 1984.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #3: Of the amounts for AR&TD, please provide approximate breakouts in FY 1984 and FY 1985 of the amounts dedicated to national laboratories, energy technology centers, universities, and industrial laboratories.

Answer: AR&TD PERFORMER BREAKOUT

| | $ in Millions | |
|---|---|---|
| | FY 1984 | FY 1985 |
| Universities | $ 9.8 (25%) | $10.7 (27%) |
| National Laboratories | 8.9 (22%) | 8.3 (21%) |
| Energy Technology Centers | 6.6 (17%) | 7.9 (19%) |
| Industrial Laboratories (including Not-For-Profit institutions, non DOE labs, National Academy of Sciences, etc.) | 14.0 (36%) | 13.4 (33%) |
| | $39.2 (100%) | $40.3 (100%) |

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #4: Do you have a unified method for soliciting or selecting research projects in the various areas of AR&TD? If not, please describe methods used in each of the categories. To the extent that they differ, please explain the basis for the differing systems.

Answer: Fossil Energy (FE) does not restrict the mechanisms to be employed for soliciting or selecting research projects in the various areas of AR&TD. Different vehicles are used based upon the particular technology and what is considered to be the best solicitation mechanism to obtain the highest quality and most relevant proposals. For example, in the University Coal Research Program, FE uses a Program Solicitation. The categories for which proposals are sought include coal science (analytical, characteristics and chemical structure); surface science (catalysts); reaction chemistry (hydrogen transport, asphaltine/polymer chemistry and reactive intermediates); mechanisms and kinetics (liquefaction, gasification, combustion); thermodynamics; and solids transport.

Proposals in the liquefaction processes program are currently sought by means of a Program Research and Development Announcement (PRDA). This form of solicitation is appropriate where proposals are sought within broadly defined areas of research and a multiplicity of projects in the same area are sought to achieve program goals. The proposals are evaluated and ranked based on criteria that give predominant weight to scientific merit and qualifications of the personnel that will perform the research. The most highly ranked proposals are invariably chosen for award, with due regard for program balance and avoidance of duplication of research.

Unsolicited proposals are also a source which all of our AR&TD programs access for novel concepts to enrich the portfolio of projects that are supported.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #5: This activity involves coordinating fossil's international activities. Please provide a synopsis of these activities in FY 1984 and FY 1985.

Answer: The international component of the Office of Technical Coordination provides a focal point for all Fossil Energy international activities. It provides the support to both program offices and to ASFE in technical evaluations for potential cooperative projects, background briefings for both Fossil Energy and foreign visitors, briefing books, position and analysis papers, and policy recommendations. It serves to monitor Fossil Energy international projects and, in some cases, acts as program manager. It coordinates all international travel for Fossil Energy, and provides a point for external coordination with the Office of International Affairs and with other government agencies such as the Department of State.

In FY 1984 and FY 1985, and in addition to the normal support activities as briefly described above, specific activities will be as follows:

FY 1984

- Obtain formal approval within the International Energy Agency (IEA) Fossil Fuel Working Party for implementation of the Combustion Science project; convene an Executive Committee under the project, and begin research efforts.
- Assist Norway in obtaining agreement-in-principle for their proposal to the IEA on the subject of multiphase flow analysis.

- Initiate, through the IEA's Coal Research Services (London), specific technical and economic studies in the area of solids transport.
- As part of Secretary Hodel's initiative with Israel, identify specific projects for cooperation, and initiate work.
- Obtain formal agreement and approval of the implementing protocol developed for fossil energy R&D cooperation with the People's Republic of China.
- Obtain formal agreement and approval of the implementing agreement developed for fossil energy R&D cooperation with Japan; initiate first joint activities.
- Identify foreign R&D efforts specifically in the area of environmental R&D applicable to the mission and objectives of Fossil Energy programs.

FY 1985

- Provide coordination and support for the IEA's Third International Coal Conference to be held August 1985.
- Initiate first cooperative R&D project with People's Republic of China.
- Identify and implement changes to IEA-generated document dissemination procedures to insure optimum information flow to U.S. researchers.
- Initiate contacts with countries identified in FY 1984 relative to fossil energy environmental R&D to develop potential projects for cooperation.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #6: Your justifications (p. 40) discuss research on kinetics and tube erosion. Are you aware of the recent problems that the Georgetown University atmospheric fluidized bed has encountered? Have you been involved in providing technical advice? What is your opinion of the causes of the increased erosion in this facility? What actions are being taken by the University to correct these problems?

Answer: DOE/FE support for the AFB demonstration program was completed in August 1982. Since that time, DOE Conservation and Renewable Energy has provided financial support to add a steam turbine and to replace some damaged tubes. With regard to the tube erosion problem, technical advice has, and is, being given to Georgetown by DOE/FE. Further, under a DOE Conservation and Renewable Energy project, the DOE is making available to Georgetown analytical assistance by the Argonne National Laboratory specifically for the Georgetown situation.

In February 1984, a meeting was held at the Georgetown University Steam Generating Facility to discuss erosion problems in the "above bed" generating tube bank of the AFB unit. The following organizations were represented:

1. Fossil Energy, Office of Coal Utilization Systems
2. Conservation and Renewable Energy
3. Georgetown University
4. Argonne National Laboratory
5. Tennessee Valley Authority
6. Pope Engineers
7. Foster Wheeler

During the last 2,500 hours of operation, the AFB erosion rate has increased to approximately 8 mills/day causing severe damage to many of the tubes that were replaced in June of 1983. The exact extent of tube damage is not totally defined due to the difficulties and time consumption associated with tube measurement. At least 10% of the tube bank (approximately 140 tubes) will have to be plugged prior to any temporary operations. Operating data, lab testing of samples, and wear patterns, do not reveal the cause of erosion.

In order to define the problem, it was decided to plug the tubes and conduct three separate four-day tests runs. These test runs will examine fly ash reinjection, cinder trap operation, dust loading, particle velocities, and wear rates with varying operating parameters. The test runs began on February 21, 1984 and will continue through May 1984. Representatives from the Office of Coal Utilization Systems were asked to attend the subject meeting by both Georgetown and Conservation officials in order to provide technical assistance and recommendations. Following this test series, a meeting will be held in May/April 1984 to advise Georgetown University as to follow-on actions.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #7: Your justifications indicate that in FY 1984 you determined high priority research areas related to physical, chemical, and thermodynamic properties research. What are they and what criteria were used for their selection?

Answer: Previous studies have identified five priority research areas related to physical, chemical, and thermodynamic (PCT) properties research. They are: 1) the theory and measurement of PCT properties of defined systems (model compounds and mixtures of model compounds); 2) measurements of PCT properties of undefined systems (real fossil fuel liquid mixtures); 3) characterization of fossil fuel liquids; 4) data correlation; and 5) data base structure and development. Currently, the measurement of PCT properties of model compounds and the characterization of fossil fuel liquids have received the most emphasis in this program. There is currently underway a review of research priorities for the AR&TD program. When completed in the 4th quarter of FY84, this should provide a refinement to the research areas currently performed for this program.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #8: In the liquefaction and gasification processes area what basic improvements are you concentrating on and what relative impact would such improvements have, either on operating expenses or capital costs?

Answer: In the area of liquefaction processes research, efforts are targeted toward achieving two primary goals: exploration of novel concepts for coal liquefaction and improved understanding of chemical and engineering phenomena that are prevalent in coal liquefaction processes. Research on novel concepts, if successful, has the possibility of leading to processes which have substantially lower capital and operating costs (10-30%), because they entail fewer process steps or permit higher production yields and/or better product quality at reasonably higher thermal efficiencies. Some of the processes may be operable at lower temperature and pressure, thus also lowering capital costs. Research to develop improved understanding of chemical and engineering phenomena could lead to appreciably lower capital and operating costs (5-15%) through improved knowledge of desirable process conditions when producing liquids from coal.

Basic improvements in the gasification processes area are being sought in the AR&TD program in several areas. Multiphase flow studies are aimed at improved systems to move coal into and within gasifiers and can have significant (10-30%) impacts on capital and operating costs of feed systems. Various aspects of gasifier design are being addressed, including studies of catalytic mechanisms, pyrolysis and the physical characteristics of molten ash, and modeling studies. These studies are aimed at improvements that can have direct impact on both capital and operating costs. In addition, several studies are being undertaken on concepts for separation processes. Better separation methods for $H_2S$ or $CO_2$ removal, or for oxygen production, could also lead to substantially (10-30%) lower capital or operating costs.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #9: Please explain the content of your fundamental fuel cell work and why it is decreasing in FY 1985.

Answer: Fuel cell research in the Direct Utilization AR&TD (DUARTD) program is generic to all types of fuel cells; phosphoric acid, molten carbonate, and solid oxide as well as other advanced concepts. The research is conducted at national laboratories and in the private sector at universities and industrial laboratories. It deals with electrochemistry, catalysis, electrolytes and materials behavior of a fundamental nature, attempting to elucidate the physical, chemical and thermodynamic mechanisms and properties that underlie fuel cell operation.

Fundamental fuel cell work is not decreasing in FY 1985. In FY 1984, $2,000,000 of the $11,300,000 DUAR&TD budget is being directed toward fundamental work; in FY 1985, an identical amount is allocated in the total request of $10,160,000. As a percentage of total effort, the fundamental fuel cell effort is increased.

The decrease in the FY 1985 AR&TD program is fuel cells research that is developmental in nature. In FY 1984, $2,000,000, in addition to the above mentioned funds used for fundamental work, was specified by Congressional report language for "private sector investigation of phosphoric acid advanced technology efforts identified in the 4.8 Mw experiment and in the 40 kw on-site program." This work, performed for the most part by the industrial fuel cell manufacturer involved with those two demonstrations, is line R&D in nature. The FY 1985 request for DUAR&TD does not, therefore, include it.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #10: Please explain why, in a stable or decreasing budget situation, more funds are required for technical and economic analyses than were required in FY 1984.

Answer: The Technical and Economic Analyses activity is the principle source of studies and analysis that contributes to the continuing evaluation of priorities of the Fossil Energy R&D program. This includes examination of technical and economic issues which could lead to changes in the relative priorities among program elements even in a stable budget. Significant changes are occurring in the perception of the needs for long-term fossil fuel technologies, particularly the need for new coal technologies to improve the economic competitiveness and environmental acceptability of coal use in electric generation and provide opportunities for coal to be used for industrial and other applications where it is not currently used. A number of important issues affecting analysis in this area must be considered, including acid rain and other concerns related to air quality. Similarly, increased uncertainties over longer-term oil supplies and prices and the levels of imports currently projected by many sources have increased the importance of the identification and analysis of technological approaches and R&D on liquids and liquids substitutes which could ameliorate the situation. The increased funding of $400,000 will thus be used for technical and economic analysis in these areas of major concern and uncertainty.

## ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

Question #11: Please explain what your solids transport program has to do with components and the funding level for the program in both the component and the technology base synthesis areas.

Answer: The AR&TD Components program has sponsored some solids flow related research for several years. This work, along with other research addressing transport of solids as a multiphase system is necessary for the accurate design of equipment (components) common to every process utilizing coal.

To date, most solid and slurry handling equipment has been designed by empirical techniques. The development of a data base and scientific understanding of the factors affecting solids and slurry flow on a micro- and macro-scale is necessary for further improvements in component design.

The Solids Transport Program (STP) will provide a focus for efforts in this area by augmenting the work sponsored by the components program as well as the more applied work in bulk solids or multiphase flow supported throughout the whole Fossil Energy program.

Of the $1,477,000 requested in the FY 1985 budget, $477,000 has been specifically identified to support the STP program. This program was initiated in FY 1984 and was funded by a Fossil Energy program assessment. As part of this assessment to provide seed money for this new activity, Technology Base Synthesis contributed $100,000. Congress will be notified of this reallocation of funds.

## COAL LIQUEFACTION

Question #1: In indirect liquefaction why is bench scale research on new catalysts being reduced? Who are the industrial cost sharing contractors involved in this work? In catalyst development what are the main goals? Have they been reached?

Answer: Support of bench scale research on new catalysts and slurry phase reactions will be reduced consistent with the mission to provide a data base for use by industry when a commercial requirement exists. Although indirect coal liquefaction will be an important technical option to enhance the U.S. domestic supply of liquid fuels, it is generally agreed that significant use of this option probably will not occur before the end of the century. Therefore, research can effectively be pursued selectively and at a lower level of effort.

Industrial cost sharing contractors are Mobil Research and Development Corporation, Union Carbide Corporation, and Air Products and Chemicals, Inc. A competitive procurement for research is now underway, funded with FY 1984 appropriations and it is expected that any new industrial contracts also will be cost shared. It is anticipated that contractors selected for awards will be notified by April 30, 1984.

Catalyst research is a major part of the research which supports the program's objective of achieving significant improvement in thermal efficiency over available Sasol technology, if used in the U.S. The goal is to be able to design new catalysts from known components, or with newly identified components, to accomplish the desired product selectivity when marking liquid fuels from U.S. coal derived synthesis gas. This is a long range goal which requires continuing research to explain the mechanisms of known catalytic systems as well as design and evaluate new catalysts. This research is aimed at producing gasoline, gasoline blending materials, diesel fuel, and jet fuel, which are the equivalent in quality of those now obtained from petroleum.

## COAL LIQUEFACTION

Question #2: What is the annual operating cost of the liquid phase methanol facility at LaPorte, TX? Are any of the catalyst development projects previously discussed amenable to being run in the same facility? If one or several of these processes were ready to be scaled up would they be compatible with the facility as it exists? Are any of these projects near the stage of being able to be scaled up?

Answer: The current operating cost of the LaPorte facility, including laboratory support is approximately $4,300,000 annually. Future operating costs may be about $5,000,000 annually, partly to provide additional feed gas required in order to obtain the desired data.

The previously discussed catalyst development projects produce fuels other than methanol. Further research with these catalysts in this facility would require major modifications to the existing facility. For example, a longer reactor will be necessary, and added equipment will be required to separate powdered catalyst from the high boiling material produced in the reactor. The processes would not be compatible with the facility as it exists.

By 1986, the slurry phase first stage of Mobil's two-stage technology will be ready for scaleup. Data from larger-scale slurry phase reaction studies could be significant for the evaluation of other catalyst systems under development.

## COAL LIQUEFACTION

Question #3: What are the costs of operating the Wilsonville, AL, facility on an annual basis? What have been the results of testing two-stage liquefaction at that facility? What technical problems remain in the two-stage liquefaction process? Please explain the difference between this facility and the Lummus two-stage liquefaction facility in New Jersey. Could the same type of experiments that are run at Wilsonville be done at the Lummus facility? What is the annual operating cost of the Lummus facility? If both of these facilities are shut down, are there any facilities, other than bench scale facilities, for work on advanced liquefaction processes?

Answer: Operating costs for Wilsonville during the current operating period are running at the rate of $9,600,000 per year. In addition, capital requirements have averaged $1,500,000 per year, resulting in total project costs of $11,100,000 per year. Over the life of the project the total project costs have been cofunded by DOE and EPRI in the ratio of two (DOE) to one (EPRI). On that basis the DOE funding requirement is about $7,400,000 per year.

Wilsonville has just completed integrated two-stage liquefaction operations on an eastern (Illinois) bituminous coal. Results showed that this process concept is capable of providing up to a 15% improvement in liquid yields at lower hydrogen consumption than second generation (H-Coal, EDS, SRC-II) process concepts. This achievement has received much attention in the technical press. In FY 1984, two stage operation using lower cost subbituminous coal will be initiated. While the operations at Wilsonville has demonstrated improved performance of the two-stage liquefaction concept, there are technical problems remaining such as:

1. Catalyst life - Catalyst activity decline has been more severe than desired and improved catalyst life is an important economic

parameter. Improvements in hydrotreater feed quality and changes in recycle stream configuration are potential avenues for improvement.

2. Lower energy rejection in the ash stream would improve thermal efficiency and increase liquid yield.

3. Increased throughput in the hydrotreater would provide large capital cost savings.

Bench scale work in these areas is underway at Lummus and Kerr-McGee in FY 1984. In addition, further testing would be required to broaden the range and type of coals evaluated in the integrated two-stage process.

The Lummus facility is a bench scale unit with a capacity of about 0.25 tons/day. Wilsonville is a 6 TPD facility utilizing industrial prototype equipment which can generate engineering and unit process operating data required by industry for evaluation of commercial potential. This information is not available from laboratory type equipment used in bench scale units. You can run the same types of experiments at the Wilsonville and the Lummus facilities, but the type of information available is not the same. Both Lummus and Wilsonville can give material balance and yield data, but only Wilsonville can provide the engineering and operational data required to establish the technical soundness of the process. Annual operating costs of the Lummus project are now running about $5,300,000 per year. This is a cost shared project with DOE funding of 85 percent, or $4,500,000 per year.

Kerr-McGee has an 11 pound/hr. integrated, continuous two-stage liquefaction research facility in Oklahoma. We are cofunding a project with EPRI and Kerr-McGee at this facility. This project is scheduled for completion at the end of FY 1984. HRI has a smaller (1 pound/hr.) integrated bench scale unit investigating a close coupled staged direct liquefaction process concept. This project is scheduled through June 1985. These, plus Lummus and Wilsonville are the only integrated process facilities working on advanced, direct liquefaction processes.

## COAL LIQUEFACTION

Question #4: In your advanced process development, as in the previously discussed indirect liquefaction activity, your work with industrial firms on catalysts is being reduced. Of what importance are catalysts to improving the direct liquefaction technology? Assuming they have some importance, why is it not necessary to continue some support of industrial development of such catalysts?

Answer: In order to produce petroleum substitute liquids from coal by direct liquefaction, the following chemical transformations need to be carried out: dissolution of coal to heavy hydrocarbon material; hydrogeneration and cracking of these materials to lighter hydrocarbons, and removal of the heteroatom impurities (sulfur, nitrogen, oxygen) in these materials. Catalysis plays a dominant role in the second and third set of reactions and therefore catalysis is a critical element in improving direct liquefaction technology.

Commercial catalysts, used in hydrotreating heavier petroleum fractions, have been used in direct catalytic coal liquefaction (H-Coal). In addition, previous coal liquefaction catalyst development work has resulted in an improved catalyst that was also tested in the H-Coal pilot plant. In FY 1984, we are continuing a catalyst development and evaluation project with American Cyanamid, based on a class of proprietary catalysts they have developed and which has shown promise in petroleum hydroprocessing. This project is scheduled for completion at the end of FY 1984. If this project is successful in identifying improved direct liquefaction catalysts, these materials could be further evaluated in bench scale liquefaction process research projects in FY 1985. The pace of industrial catalyst development is being stretched out consistent with the current estimate of the time frame for the commercialization of the Coal Liquefaction technologies.

## COAL LIQUEFACTION

Question #5: Are two-stage liquefaction processes advanced enough to be considered substitutable on a commercial scale for such processes as H-Coal, SRC, or the donor solvent process?

Answer: The two-stage liquefaction process concept has been developed at the bench scale and evaluated with a bituminous coal at the 6 TPD Wilsonville proof-of-concept facility. By contrast both EDS and H-Coal have been operated at the 200-250 TPD pilot plant scale on a variety of coals. As a result of these operations, both the EDS and H-Coal processes are available for commercial licensing by the developers (Exxon, HRI). Because of the limited scope and scale of operations we do not believe that the two stage process concept can be considered advanced enough for commercial scale application. There is no industrial developer now offering this type of process for licensing.

## COAL LIQUEFACTION

Question #6: Do you have any plans to investigate the possibility of using slurry mixtures of coal and oil in refineries and refining processes?

Answer: In FY 1984 we are planning to initiate, through competitive procurement, a project in coprocessing of coal with petroleum residuum. This process concept eliminates or substantially reduces the requirements for the recycle of large amounts of internal process oil, and therefore offers the potential for substantial capital cost reduction. Domestic petroleum refineries are being modified and upgraded to use heavier petroleum crude which will constitute an increasing amount of the future crude oil supply. Much of the equipment and technology required to process these heavier crudes can be utilized in coprocessing of coal with petroleum. In that sense, this coprocessing concept offers the potential for accelerating the introduction of coal-derived fuels into the marketplace by utilizing, to a substantial degree, existing petroleum refining technology and equipment. More details on this project will be made available when the procurement has been awarded.

## COMBUSTION SYSTEMS

Question #1: What role, if any, is the fossil energy organization contemplating in the TVA fluidized bed demonstration facility?

Answer: DOE involvement in the EPRI/TVA AFB demonstration project will not be finalized for another several months. However, DOE's role is expected to be somewhat minor, since TVA is responsible for AFB utility applications versus the Department's industrial application responsibility. DOE will probably limit its involvement primarily to the operation phase of the project.

DOE feels that by successfully integrating appropriate research needs of the DOE AFBC program into the test program for the TVA demonstration, significant benefit can be derived from the availability of such scaled data. The key to this integration activity is a close cooperative relationship among DOE, TVA and EPRI. DOE does not desire any management role in this project, but rather to be apprised of events in the development and operation of the demonstration plant.

DOE, in its desire to develop a coordinated two-year research plan with TVA and EPRI, will work closely with both organizations to assist in the development of test/operational plans that support DOE's needs without compromising the TVA effort. To initiate and facilitate this development, DOE will request data such as:

- Demonstration design and process parameters.
- Pilot plant data used in establishing the parameters.
- Start-up and operational schedule.

- Operating cost estimate for the demonstration plant.
- Preliminary test plans, goals, objectives, and activities to be undertaken.
- Final test plans.
- Monthly reports.
- Special or topical reports on component performance, unexpected events, etc.
- System optimization studies.
- Economic assessment of a commercial plant.
- Analysis of all feedstocks and wastes.
- Backup samples for DOE of solid samples from particulate cleanup systems, the FBC bed and feedstocks.
- Assessment of the environmental significance of gaseous/particulate emmissions, solid wastes, and performance of emission control systems.

## COMBUSTION SYSTEMS

Question #2: Please review the atmospheric fluidized bed contracts that were awarded in April of 1982, including a description of those processes which were allowed to go to bench scale testing. What advantages do these processes appear to have, if any, over existing AFB technology?

Answer: The primary objective of the Atmospheric Fluidized Bed (AFB) program is to develop a direct combustion technology for industrial boiler applications that is capable of burning coal of various ranks in a technical, economic and environmentally acceptable manner. Development of AFB technology will offer the private sector an alternative to conventional coal combustion technology and will displace oil and natural gas consumption by encouraging the use of domestic coal reserves as fuel. The objective of the "Base AFB program" is to develop first generation AFB technology for large industrial boiler applications (200,000 lb/hr steam and greater) by 1985. The objective of the "Advanced AFB Program" is to develop advanced or second generation AFB concepts for small industrial boiler applications (50,000 - 200,000 lb/hr steam) by 1990.

In April 1982, DOE awarded seven conceptual design studies for advanced AFB technology. Summary descriptions of the various concepts are shown in Attachment 1.

Advanced AFB Program Goals

- The advanced AFB program will emphasize significant economic improvements over base AFB technology. These economic goals are a 25 percent reduction in total capital equipment cost and a 10 percent reduction in operational costs.

- The advanced AFB program stresses the following technical improvements over base AFB technology:

Efficiency: Minimum boiler efficiency of 85%
Minimum carbon capture of 98%
Minimum sorbent reactivity of 80%
Minimum turndown ratio of 5:1

Reliability: Minimum system availability of 92% (on-line capability of 48 weeks per calendar year).

Environmental Emissions (all coal types):
Minimum $SO_x$ removal of 90%
Maximum $NO_x$ emissions of .4 $lb/10^6$ Btu
Maximum particulate emission of .03 $lb/10^6$ Btu

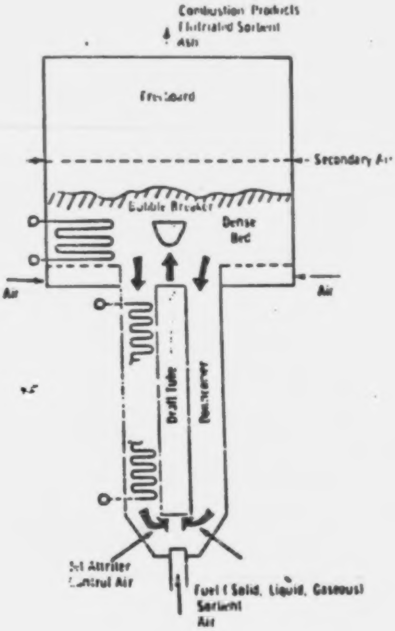
- The advanced AFB program shall stress simplicity and reliability of coal feed, ash handling, and environmental equipment.

The seven advanced concepts shown in Attachment 1 are in the final stages of evaluation for follow-on efforts. Economic system studies of all concepts will precede the bench scale testing of two concepts.

## WESTINGHOUSE

The Westinghouse concept for an advanced AFBC is an internally circulating bed. Sorbent (limestone) may be fed into the base of the vessel, at a small number of coal feed points, by penumatic transport with substoichiometric air. The entrained fuel passes upward through a centrally positioned high velocity draft tube along with circulating sorbent, char, and fuel ash. This material descends the downcomer region surrounding the draft tube, either as a moving bed or a slightly fluidized bed. The rate of circulation is controlled by the amount of fluidizing gas injected into the downcomer. Heat transfer surface may be placed in the downcomer, as well as in the upper fluidized bed, depending upon the fuel, excess air, and control requirements of the application. The upper fluidized bed is a deep bubbling bed.

This design is anticipated to lend itself to fuel flexibility, high levels of turndown, high carbon efficiency and lower captial and operating costs due to reduced fuel feed ports.


Combustion Products
Elutriated Sorbent
Ash
Freeboard
Secondary Air
Bubble Breaker
Dense Bed
Air
Air
Draft Tube
Downcomer
Jet Attriter
Control Air
Fuel (Solid, Liquid, Gaseous)
Sorbent
Air

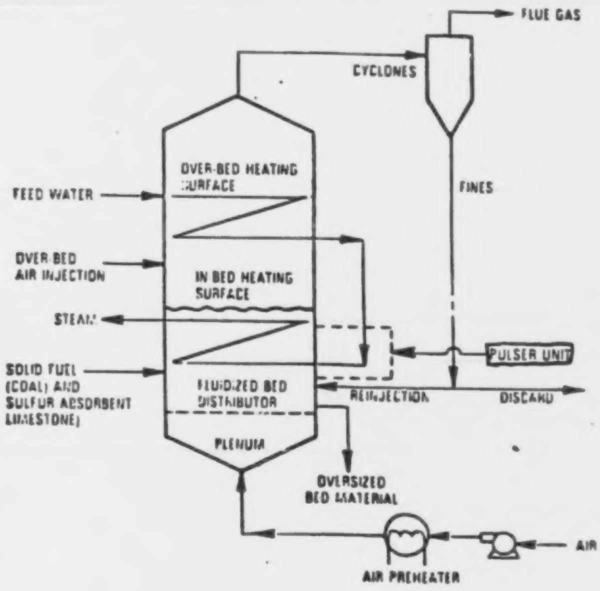
## A.D. LITTLE

A. D. Little proposes to superimpose a secondary pulsed air flow on the steady air flow of a conventional AFBC. Generally flow pulsation is expected to increase the heat and mass transfer across the boundary layers surrounding the coal and inert particles and hence improve system performance.

Literature data will be collected and analyzed to characterize the effects of pulsations on key processes in an AFBC, such as fluidization and bubble formation, coal heating and devolatilization, volatile and char combustion, production of $SO_2$ and its removal by the sorbent, emission of CO and $NO_x$ and heat transfer to immersed heat exchangers. This characterization will provide the supporting data for concept development. Data gaps and uncertainties will be identified to form the basis for a bench-scale testing program.

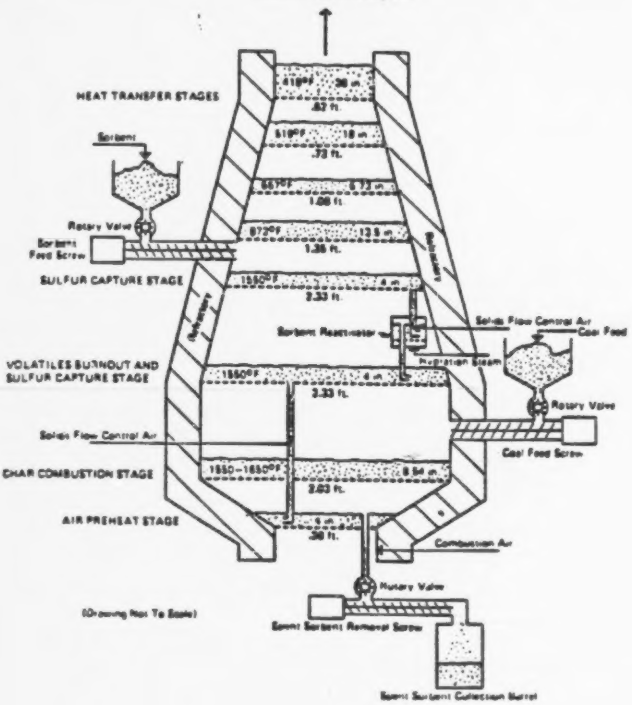
Various conceptual designs will be examined for providing flow pulsations and for comparing their advantages and disadvantages. A preferred design will be selected to perform heat and mass balances and to compare the results with convenstional AFBC systems.

It is anticipated that this concept will enhance carbon burnup efficiency and sorbent utilization.


FLUE GAS
CYCLONES
FINES
OVER-BED HEATING SURFACE
FEED WATER
OVER-BED AIR INJECTION
IN BED HEATING SURFACE
STEAM
PULSER UNIT
SOLID FUEL (COAL) AND SULFUR ADSORBENT LIMESTONE)
FLUIDIZED BED DISTRIBUTOR
REINJECTION
DISCARD
PLENUM
OVERSIZED BED MATERIAL
AIR
AIR PREHEATER

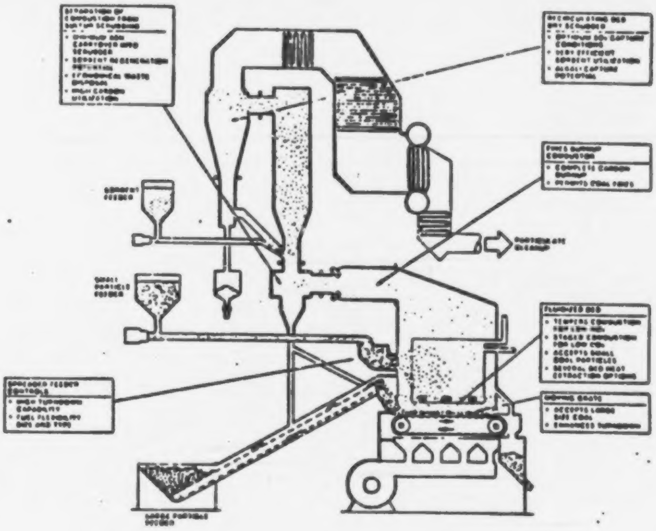
[3]

Operation of the Staged Cascade Fluid Bed Combusor (SCFBC) is similar to a continuous distillation column, except that its primary function is to carry out heat transfer and chemical reaction processes, as opposed to mass transfer processes. The liquid phase in a distillation column is replaced by a fluidized solids phase in the SCFBC. Limestone is fed into the top stage of the boiler, combustion air is fed to the bottom stage, and coal is fed to a stage near the center of the boiler. Each stage is constructed of water-wall boiler tubing with orifices or bubble caps placed in the webbing between tubes to permit the passage of fluidizing gas. The webbed water-wall tubing serves as the distributor plate to support fluidized solids, and as a conduit for the steam circuit. Solids flow from a downcomer in the stage above and through an orifice onto the subsequent stage, where the solids are fluidized by gas passing through the distributor plate. The height of the solids in the bed is controlled by the overflow weir. Solids leave a stage flowing over the weir and into the downcomer leading to the stage below. The spent sorbent and ash are cooled by preheating combustion air and drain from the bottom of the system. One of the principal advantages of this design is better sorbent utilization (sulfur clean-up) and high combustion efficiency.


Off Gas to Cyclones & Baghouse
HEAT TRANSFER STAGES
419°F
36 in.
.82 ft.
519°F
18 in.
.73 ft.
667°F
6.73 in.
1.08 ft.
872°F
13.5 in.
1.36 ft.
Sorbent
Rotary Valve
Sorbent Feed Screw
Refractory
SULFUR CAPTURE STAGE
1550°F
4 in.
2.33 ft.
Solids Flow Control Air
Coal Feed
Sorbent Reactivator
Hydration Steam
VOLATILES BURNOUT AND SULFUR CAPTURE STAGE
1550°F
4 in.
2.33 ft.
Rotary Valve
Solids Flow Control Air
Coal Feed Screw
CHAR COMBUSTION STAGE
1550–1650°F
8.94 in.
2.03 ft.
AIR PREHEAT STAGE
6 in.
.38 ft.
Combustion Air
Rotary Valve
(Drawing Not To Scale)
Spent Sorbent Removal Screw
Spent Sorbent Collection Barrel

## AEROJET

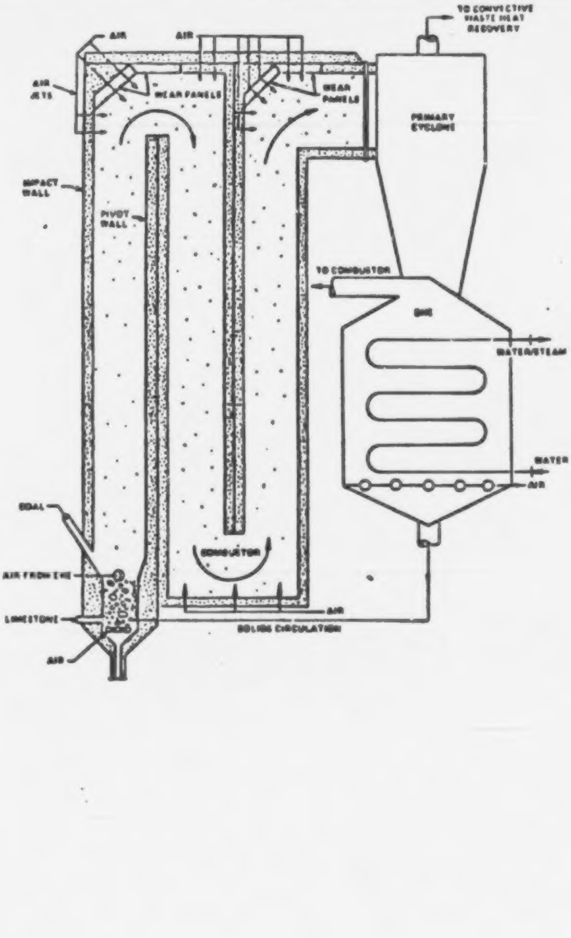
The Aerojet system has incorporated the best features of the conventional Atmospheric Fluidized Bed Combustion (AFBC) system and the conventional stoker system. It can use a wide range of coals and coal sizes, and has a high turndown ratio like a stoker. It can maintain a uniform combustion environment under a wide variety of conditions with low pollution emissions like an AFBC system. In addition, it may also be possible to use the system to clean up alkalis, to allow a wider range of coals to be burned without compromising the operating life of the system due to alkali corrosion. The use of a self-cleaning distributor plate allows the removal of ash from the combustion furnace whether or not the furnace is fluidized. The conflicting requirements of having air velocity low enough to minimize elutriation of the smaller particles and high enough to fluidize the larger particles results in a system with very little leeway for turndown. The capability to remove the ash eliminates the absolute necessity for fluidization, so the turndown can be extended at the low end.



## BATTELLE - ULTRA HIGH VELOCITY

The main design feature of the Battelle Ultra High Velocity Combustor (UHVC) is the high velocity allowed in the fluid bed combustor while maintaining an extended freeborad reaction zone. The UHVC design approaches 100 feet/second, which is significantly higher than that permitted by current technology. The design described simplifies feeding methods, allows high turndown, achieves high levels of $NO_x$ and $SO_x$ emission control, and permits unusual fuel versatility.

The UHVC concept is a circulating bed design where rapidly moving small particles are passed through a "conventional" fluid bed of large particles which form the main combustion zone. The circulating particles are restrained by interaction with the dense bed in the main combustion zone to increase solids residence time. The circulating particles are transported to a cyclone separated from the gas stream and dropped into a second, relatively quiescent, fluid bed. Tubes submerged in the quiescent bed remove heat to form steam thus cooling the solids. The cooled solids are then returned to the combustor for reheating and transport. Emissions of $SO_2$ and $NO_x$ will be controlled by limestone addition and staged combustion.


TO CONVECTIVE WASTE HEAT RECOVERY
AIR
AIR
AIR JETS
WEAR PANELS
WEAR PANELS
PRIMARY CYCLONE
IMPACT WALL
PIVOT WALL
TO COMBUSTOR
EHE
WATER/STEAM
WATER
AIR
COAL
COMBUSTOR
AIR FROM EHE
LIMESTONE
AIR
AIR
SOLIDS CIRCULATION

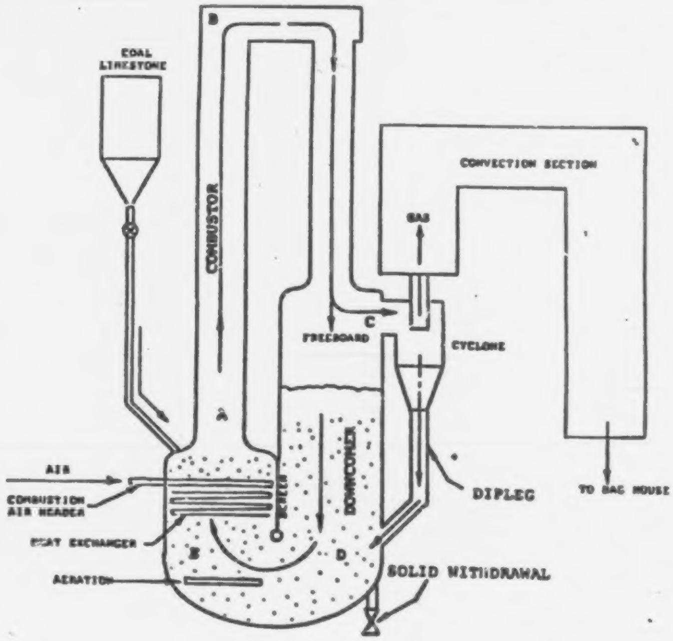
## KELLOGG

Coal and limestone are fed by gravity into the combustor at a location that is a highly-turbulent region where combustion air, feed coal and limestone, and recirculating solids are mixed. The feed solids constitute less that 1 percent of the circulating solids.

The mixture of solids and air flow upward into a cylindrical cross section where the gas and solids are accelerated to as high as 60 fps and then reverse direction through two, ninety-degree bends, in what is commonly termed a folded riser in the process industries. The turbulent inlet, the high gas velocity, and the two bends insure excellent gas-solid contacting throughout the system.

The folded riser discharges into a disengager and the gas accelerates here to higher velocities (100 to 150 fps) as it enters the cyclones. Approximately 50 percent of the solids are disengaged prior to the turn into the cyclone and are decelerated in the downcomer. The solids entering the cyclone are separated and returned to the bottom of the downcomer.

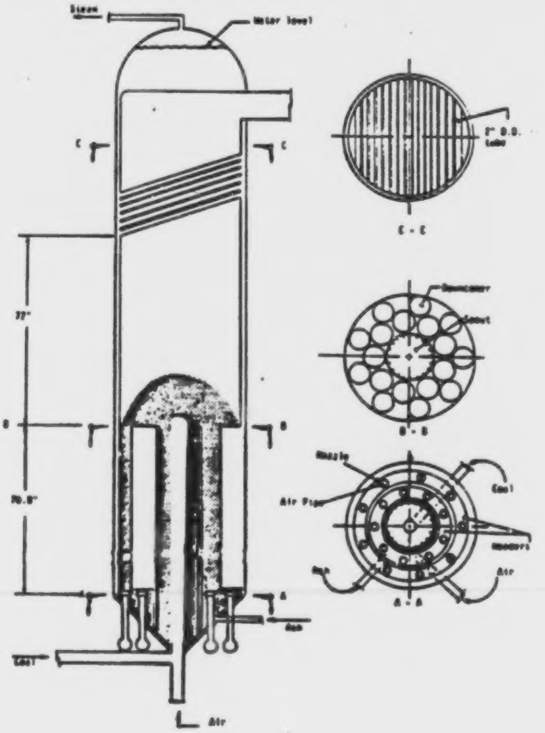
The benefits expected from this concept is reduced operating costs due to lower limestone consumption, increased volumetric heat release, improved turndown and fuel flexibility.


B
COAL
LIMESTONE
COMBUSTOR
CONVECTION SECTION
GAS
C
FREEBOARD
CYCLONE
A
AIR
COMBUSTION
AIR HEADER
SCREEN
DOWNCOMER
DIPLEG
TO BAG HOUSE
HEAT EXCHANGER
E
D
AERATION
SOLID WITHDRAWAL

## BATTELLE - SPOUTED

The Battelle spouted bed consists of relatively coarse solid particles partly filling a cylindrical vessel, which is provided with a small, centrally located inlet aperture in its base, which is usually conical. Air injected through this inlet at velocities beyond a certain minimum value will cause a stream of particles to rise rapicly in a hollow central core (the "spout") forming a fountain above the peripheral spout and the wall, and thereafter travel slowly under gravity in a dense phase with some countercurrent percolation of fluid, establishing a systemmatic cyclic pattern of particle movement. This is in contrast to the largely random movement in a conventional fluidized bed. This designs permits burning coarse size fuels with low heating values, and significantly extends the range of fuels that can be used economically.

The spouted bed can normally be operated efficiencly at higher superficial velocities than those of conventional design. As a consequence, higher combustion intensities than conventional in fluidized beds are possible with the spouted bed (with the same particles and bed height). Spouting induces nearly perfect solids mixing, both in the axial and in the lateral direction. It is not as sensitive to particle size and shape as is conventional fluidization because of the high local velocities and the distinct circulation pattern which exists. This introduces the possibility of reducing the number of fuel feeding ports, and of handling as-received coal with minimum preparation.



## COMBUSTION SYSTEMS

Question #3: Please describe the current status of the Grimethorpe facility.

Answer: The facility at present is being operated using United States coal and dolomite. The purpose of the current test series is to characterize plant performance with an updated tube bank configuration and to evaluate tertiary cleanup performance. Plant operations will be completed in May 1984 at which time the title to the facility will be transferred to the National Coal Board. A technology transfer workshop is planned for July 1984 to present Grimethorpe data to U.S. industry. DOE participation in the current program, which is jointly sponsored by the U.S., U.K., and F.R.G. under the auspices of the International Energy Agency, will be concluded in January 1985 after final project reports are completed and distributed to U.S. industry.

The staffs of the British National Coal Board and the Central Electricity Generating Board are preparing a plan for a test program to be conducted at Grimethorpe after the IEA program has been completed. The Boards are expected to decide, in the near future, whether to support an additional test program. If a positive decision is made, it will be on its merits as a British project.

In FY 1984, $1.5 million was appropriated to DOE for additional tests at Grimethorpe. Both DOE and the British have decided to await the British decision, on a program of tests to follow the IEA program, before discussing U.S. DOE participation.

## COMBUSTION SYSTEMS

Question #4: With regard to pressurized fluidized beds, are there any concepts being discussed by industry with you for the utilization of DOE funding to assist in determining whether to go ahead with a demonstration facility? If so, please describe the scope and content of these discussions.

Answer: Discussions have taken place with representatives of the General Electric Company and Babcock and Wilcox regarding a proposed PFB demonstration project with Florida Power and Light. These discussions mainly dealt with technical areas of concern which require resolution prior to commitment for construction and operation of the demonstration plant. The greatest technology risk reported by industry is the in-bed erosion of the heat exchanger tube bundle. The DOE PFB program is geared to provide industry with the basic technological data needed for their decision making for private sector funding of a demonstration project.

## COMBUSTION SYSTEMS

Question #5: What is the status of the Wood-Ridge, NJ pilot plant? What are your plans for its operation? Please describe the general concept of operation and the experimental program, and how it would differ from those programs already completed or under way in other facilities such as Grimethorpe or CURL. What interest have you generated, either in industry or with the Electric Power Research Institute, in the test program at this facility?

Answer: Construction of the pressurized fluidized bed pilot plant was completed in November 1983. Attempts by the Curtiss-Wright Corp., which constructed the plant under a cooperative agreement with DOE, were unsuccessful in securing private sector funding to operate the facility. In FY 1984, the Department plans to determine if potential cost-sharing partners are interested in using the Wood-Ridge facility to acquire data and experience. Funds are requested in FY 1985 to permit the Department to participate in such cost-sharing arrangements. If no such partner is obtained, the facility would be placed in standby until future needs are determined. In this event, the requested funds would be applied to an ongoing effort to better define the overall R&D needs of PFB technology and to enhance the compilation of a sound technological data base on the PFB concept.

Utilization of the facility would offer system integration testing involving the gas turbine and PFB combustor in addition to demonstrating a workable controls system, reliable solids feeding and ash let down systems and long term operational reliability. The Grimethorpe facility only provides combustor information, and the CURL facility is limited to basic PFB research testing.

The Electric Power Research Institute (EPRI) has long supported development of the pilot plant as a major step for achieving the necessary confidence for industry to commercialize PFB technology. DOE is presently evaluating an unsolicited proposal submitted by a team consisting of electric utilities, major equipment manufacturers and architect/engineering firms which propose a cost-shared program to operate and evaluate the Wood-Ridge, NJ, pilot plant.

## COMBUSTION SYSTEMS

Question #6: What are your plans for the continued operation of the General Electric test facility for materials?

Answer: It is planned to operate the Long Term Materials Test facility through FY 1985 to develop baseline data of the mechanisms and kinetics of materials degradation in a PFB environment. This baseline would provide the rationale from which scientifically based and prioritized materials testing can be conducted.

## COMBUSTION SYSTEMS

Question #7: Please provide a review of the technologies involved in the advanced combustion technology area, including results to date, and those projects which you intend to continue in FY 1985.

Answer: The primary objective of the Advanced Combustor program is to develop a technology for retrofit to existing oil- and gas-fired boilers which will permit coal combustion. The Advanced Combustor concept is intended to remove the coal ash prior to combustion in the boiler, while simultaneously incorporating the means to reduce emissions of oxides of nitrogen and of sulfur in order to satisfy environmental requirements. The device will accommodate combustion of either a wide range of grades and types of conventional pulverized coal, coal-water mixtures (CWM), or beneficiated coal-water mixtures (BCWM).

The contractors to the program are:

- TRW, Inc. - This low-emission system would burn the coal in stages, partially combusting the coal in the first stage and removing the molten ash or "slag". The boiler's existing firebox would be used as the second stage to complete the combustion process.

- Avco Everett Research Lab., Inc. - This system would use a compact "slagging" coal combustor design that would be mounted outside an oil-fired boiler and would prevent coal ash from entering the boiler. This design should be effective in trapping a major portion of the ash in a more energy-efficient manner than similar designs used previously. (This effort is still under discussion.)

- Science Applications, Inc. - Wet Oxidation Process that would eliminate the release of nitrogen oxides, sulfur oxides, and unburned particulates to the atmosphere.

- Energy and Environmental Research Corp. - Vortex Containment Combustor which selectively removes ash particles in a combustor much smaller than conventional designs.

- Solar Turbines, Inc. - Impact Separator Particulate Removal System that would remove the ash from the hot gases before they enter the boiler.

- Management and Technical Consultants, Inc. - Pulse Combustion Technology to burn CWM in oil-designed boilers and furnaces.

- Foster Wheeler Development Corp. - Explosive comminution of coal by mixing coal and water under high pressure, and then rapidly lowering the pressure.

Since all of these efforts are quite new (the first contract was signed in August 1983), there are no results yet. Both the TRW and Avco Everett efforts are expected to continue into FY 1985. However, only the most promising of the remaining contracts, probably three, will be funded beyond the current fiscal year.

## COMBUSTION SYSTEMS

Question #8: Please describe the scope of your work with TRW on advanced industrial or utility combustors.

Answer: The TRW work, entitled "Advanced Slagging Coal Combustion System", includes the following technical objectives:

- Removal of mineral matter from the system prior to entry into heat transfer systems.
- Minimize emissions of $SO_2$, $NO_x$, and particulates.
- System should be capable of using a wide range of coals.
- System should be scalable.

Funding support for FY 1984 provides for Phase I, "Combustor Characterization and Scaling," which consists of the following technical tasks:

- System studies.
- Characterization tests on a 10 MBtu heat input/hour combustion system.
- Scaling and performance verification tests on a 50 MBtu/hour combustor.
- System integration design.

If TRW's contract is extended to pursue Phase II, "Combustor System Interactions", the additional tasks will be:

- Secondary air injector and tube bundle fabrication.
- System interaction tests.
- Fuels evaluation.

## COMBUSTION SYSTEMS

Question #9: Please review the joint program in coal combustion you have with DOE's conservation activity, including specific projects and funding.

Answer: Conservation is jointly supporting, with Fossil Energy, the Advanced Combustor program. Both Offices are considered to be parties to the complete set of program projects; currently, this consists of the efforts identified in question #7. Actual and proposed funding levels to date by the two Offices are tabulated below:

($ in millions)

| | FY 1982 | FY 1983 | FY 1984 | FY 1985 |
|---|---|---|---|---|
| OC&RE | 1.275 | 1.0 | 0.9 | 0.9 |
| OFE | 1.056 | 3.0 | 1.7 | 2.0 |
| Total | 2.331 | 4.0 | 2.6 | 2.9 |

## COMBUSTION SYSTEMS

Question #10: Please explain what the data base need is in alternative fuels and what specific projects you have under way in order to meet it. What is the industrial response to your program in coal liquid mixtures? What type of continuing activity would you expect in this area after FY 1985?

Answer: The data base need in alternative fuels is twofold. Initially, there is a need to identify and characterize the overall technical aspects of utilizing a coal-water mixture (which has been defined as combustible, handleable and storable) in stationary combustion systems while employing state-of-the-art coal handling, grinding, cleaning and mixing technology. The specific projects underway to address this are: the Combustion Engineering combustion characterization project and the TRW system component (piping, valving, metering, etc.) characterization project. Both projects specifically address state-of-the-art coal water mixtures technology in utility boilers designed for coal and presently firing oil, and oil designed utility and large industrial boilers. Preliminary investigations have defined these applications as being most feasible and possessing the least degree of technical risk when utilizing state-of-the-art CWM technology.

Secondly, we have initiated the definition of technical needs and associated research in an attempt to address a broader, higher technical risk market area which includes gas designed utility, industrial and commercial scale units; residential systems; and heat engine applications. Preliminary analyses of this market area have resulted in a technical position that "advanced techniques (in coal grinding, coal cleaning, and mixing) will be required for reasonable market penetration with a coal-liquid mixture fuel." Hence, the specific projects that we presently have underway are designed to screen initially and specify later the fuel and component requirements for CLM application in this market area.

The industrial response to our CLM program has been more than enthusiastic, (i.e., privately funded fuel preparation programs awaiting our specifications data, an annual attendance of over 500 industry types at our CLM symposium, numerous daily inquiries seeking data, etc.) and in fact represents a near ideal working relationship between industry and government in the development of a technology.

All of our post FY 1985 activities will address component and combustion specifications data generated for the aforementioned commercial, residential, and heat engine areas where research into advanced concepts of coal grinding, cleaning and handling will be required, along with other liquid medium (other than water) research.

## FUEL CELLS

Question #1: What is the status of the 4.8 Mw facility at Consolidated Edison in New York? What problems have been encountered in start-up and what needs to be done in order to have the demonstration operate properly? Is private industry expecting DOE to provide funds to the demonstration? If so, at what level? What is DOE's position on this?

Answer: The 4.8 Mw preprototype fuel cell power plant is completely installed at the Consolidated Edison site in New York City. Power operation start-up has been delayed as a result of problems recently identified with the fuel cell stacks (the power plant has 20 fuel cell stacks). One stack has a cooling water leak and must be replaced by one of the existing spare stacks. All other stacks are judged operable and power plant operation is expected to begin in May 1984. The 4.8 Mw planned tests are fully funded and additional funding requirements are not expected. This funding has been provided by DOE, the Electric Power Research Institute and Consolidated Edison.

The 4.8 Mw power plant (of similar design) built by the same company (United Technology Corporation) for the Tokyo Electric Power Company was successfully operated at part load in 1983. This power plant has now been modified to permit full power operation and will continue to be operated in 1984.

## FUEL CELLS

Question #2: Why are you reducing the level of work in the electic utility R&D area and the on-site technology development area?

Answer: The on-site utility and field applications tests referred to here represent activities which we believe should be supported by the private sector. These integrated power systems are approaching true commercial prototypes; consequently, they are more significant in their commercial aspects than in their research value. We believe that in keeping with the underlying DOE/Fossil Energy mission, it is more important to direct our resources in fuel cells to longer range, higher risk growth versions.

## FUEL CELLS

Question #3: What is the status of your contracts with UTC and Westinghouse for the development of phosphoric acid systems? What is your estimate of the time needed until this technology is commercial?

Answer: UTC Electric Utility Technology Development - 11 MW Power Plant Stack Development

- Full area (10 square feet) cell components produced.
- Full area (10 square feet) cell stack of 30 cells being tested.
- Early cooler plate edge cracks have been eliminated in later full size (10 square feet) components.
- Draft power plant specifications completed by Booze Allen under EPRI contract.
- Independent cost analysis, made by Booze, Allen and Hamilton under EPRI contract, for the 11MW technology substantiate the cost reduction projections of $500 per KW below the manufacturing costs of the 4.8 MW fuel cell stack technology.

Westinghouse Electric Utility Technology Development - 7.5 MW Power Plant Stack Development

- Full area nine cell stacks, nine test stacks operated.
- Persistent difficulties; cell leaks and low cell performance.
- Alternate seals and matrix materials being evaluated; progress in electrolyte volume and concentration control expected to reduce cross leaks.
- Alternate catalysts show promise; binary and ternary platinum alloys; modified catalyst sintering also promising.

- Alternate carbon treatments and operating conditions being evaluated for reducing corrosion.
- Technology base development is scheduled to be completed in 1986, but is currently being reassessed due to difficulties experienced in achieving required cell and stack performance.

On-Site Technology Development

- UTC - Cell/stack technology development optimization continuing (dual porosity substrates, encapsulated coolers, catalysts and catalyst supports).
  - 30 cell stack operating; approximately 4000 hour of 5000 hour test; full stack tests scheduled for FY 1985.

- Engelhard - Successfully completed 500 hour test of 5 kw system.
  - Development areas ongoing; auto electrolyte replenishment, commercial graphite bipolar plate, nonmetallic cooling plate.
  - Engelhard to commercialize 100 kw system. Engelhard is expected to commercialize on-site fuel cell systems (nominally 100 kw) in the 1988-1990 time period.

It is estimated that U.S. industry should be in a position to make a commercial system offering sometime in the late 1980s.

## FUEL CELLS

Question #4: Please explain the current status of the on-site phosphoric acid demonstration program. What is your estimate of the timing for commercialization of this technology?

Answer: Four 40 kw power plants are installed at user sites. Two units at Southern California Gas are operating. The remaining two units (one in Baltimore and one in Michigan) are shut down for weather related problems (Michigan) and a controller problem (Baltimore). By the end of February 1984, eleven units will have been installed in the field. All units are scheduled to have been acceptance tested at United Technologies by October 31, 1984.

The DOE Office of Fossil Energy fuel cells program is focused on the resolution of the key technical issues impeding private sector commercialization initiatives. The DOE is, at present, supporting the development of three types of fuel cells (characterized by the cell electrolyte used) — phosphoric acid systems, molten carbonate systems, and solid oxide systems. Phosphoric acid technology is the furthest developed with two 4.8 Mw electric utility preprototype power plants in operation, or about to be placed into operation, and approximately fifty 40 kw power plants being fabricated for subsequent field testing in on-site applications. The integrated system experience gained from the operation of the 4.8 Mw and 40 kw power plants coupled with the technology base that will be developed under the present R&D efforts will provide the foundation for a private sector initiative leading to the commercialization of this technology. The Federally funded R&D efforts will culminate in the operation of advanced full scale fuel cell stacks. Barring unforeseen technical problems, it is anticipated that this work will be completed in the next one to three years. Further development and subsequent commercialization will be the responsibility of the private sector.

The technology is anticipated to be commercially available in the late 1980's after significant experience of these field units has been satisfactorily completed.

## FUEL CELLS

Question #5: Are you planning to continue the work on the second on-site technology involving an organic coolant?

Answer: In FY 1984, DOE is supporting the technology development of an alternate, organic-cooled on-site technology at Engelhard. FY 1984 funding is approximately $1,500,000. There are no funds included for this activity in the FY 1985 budget request. In FY 1985, the on-site technology development program will be restructured to elminate parallel development activities in order to permit a least cost development strategy without significantly increasing development risk.

## FUEL CELLS

**Question #6:** Please explain why you are reducing one of the development efforts in molten carbonate systems. Does that leave you with two efforts? Please explain the differences among the three efforts you are involved in currently. What is the advantage of internal fuel reforming, and will you continue that program in FY 1985?

**Answer:** Technical problems in molten carbonate stack development encountered in FY 1983 and FY 1984 necessitated a reduced pace of development, and an emphasis on technology based efforts to find solutions to the materials and design related problems. The ongoing federally supported development effort with General Electric is scheduled to be completed in December 1984. On this basis, the molten carbonate program will have one principal technology development activity at UTC, and in addition, will include technology based efforts on cell internal reforming at ERC.

The UTC system is an externally manifolded system and is much further developed than alternate systems. The ERC effort for technology development of cell internal fuel reforming potentially offers cost and efficiency advantages. Compared to a molten carbonate fuel cell system obtaining hydrogen-rich gas from a reformer (reforming natural gas), the internal fuel reforming system will have an efficiency gain of about 10 percent (5 percentage points). The cost reduction based on the same systems comparison is estimated at up to 30 percent. Internal fuel reforming technology development will be continued in FY 1985.

## FUEL CELLS

Question #7: Once a submodule is constructed in the solid oxide development what would the next step be? Do you plan to continue beyond the submodule development?

Answer: The next step following test completion of the 24 cell submodule is to fabricate and qualify a 5 kw module. Qualification of the 5 kw module is planned to be completed in FY 1986. Continuation of development beyond the submodule qualification stage will be strongly influenced by the results of submodule testing.

## FUEL CELLS

Question #8: Please explain briefly what contracts have been transferred to the nuclear program in the thermionics area and what the overall results have been to date in this technology.

Answer: The responsibility for management of the thermionic research contracts with Thermo-Electron Corporation, Rasor Associates, and Arizona State University was transferred from DOE/Fossil Energy (specifically, the DOE Chicago Operations Office) to DOE/Nuclear Energy (specifically, the DOE San Francisco Operations Office) in the first quarter of FY 1984.

The FY 1983 results included the operation of a test stand for several hours burning a coal-oil mixture. A recent advancement by Rasor Associates reduced the gap between the emitter and the collector from the normal 20-30 thousandths of an inch to as small as .5 to 1.0 thousandths. This is expected to increase appreciably the efficiency of the converter.

## FUEL CELLS

Question #9: Please explain the status of fuel cell applications to other than utility and on-site electric requirements, such as those related to railroad, marine, trucks, and busses. Are you supporting any work in this area? If so, please describe it.

Answer: The DOE Office of Fossil Energy is funding (FY 1984) a $200,000 study by Los Alamos National Laboratory to examine fuel cell applications other than electric utility and on-site electricity generation. Earlier phases of this study indicated that fuel cell powered transportation may be feasible in the future. Transportation applications of fuel cells are expected to occur after the initial fuel cell products are commercialized. Catalyst, electrolyte and materials development work being performed for electric utility and on-site applications are expected also to directly contribute to transportation applications.

## HEAT ENGINES

Question #1: Please explain how your heat engine program ties into the combustor and diesel work involved in the conservation program.

Answer: The Conservation diesel program is oriented towards large, slow speed, stationary engines intended for cogeneration services whereas the Fossil Energy program points more generally to medium speed utility and heavy transport designs. Communication is being maintained between responsible Headquarters and field program personnel with respect to objectives, activities, and supporting research.

## HEAT ENGINES

Question #2: For each of the two engines involved, turbines and diesels, please describe what you consider the main problems in using coal based fuels and how you are moving to attempt to solve those problems.

Answer: The principal problems with coal-derived fuels are combustion behavior and impurity effects. Principal research response to these problems, in the case of coal-derived gas fired turbines, include removal of impurities from the hot, raw, gas by cycloning and desulfurization; and cooling of turbine components to suppress corrosion and deposition. In the case of coal slurry fired turbines, principal efforts are focused on advanced combustor designs to suppress $NO_x$ formation and ensure high combustion efficiency, and screening tests of advanced coal slurry fuels to ensure highest available quality. In the case of coal-fired diesels, major attention, so far, has been directed toward the development of design conditions necessary for the injection and combustion of slurry fuels under simulated diesel operating conditions.

## HEAT ENGINES

Question #3: How is your work in the heat engine area tied to the development of combustors in the combustion area? Can those combustors be used for the turbine program?

Answer: Two stage, cyclonic combustor designs that are being evaluated under the advanced combustion program are highly relevant to the turbine program to the extent that they could improve the ultimate quality of the gas stream at the turbine nozzle. Close technical communication has been established to this end. Also fluid bed combustors may offer opportunities to again improve the quality of combustion gases at the turbine inlet by preheating the combustion air supply in an in-bed metallic heat exchanger.

## HEAT ENGINES

Question #4: Please describe the turbine industry's involvement in this activity and what they see as the major problems or advantages of the use of coal.

Answer: Major gas turbine manufacturers are participating i.e., General Electric (coal-derived gaseous fuel, hot gas cleanup, water cooled turbine component tests, and system studies); Westinghouse (combustion research, and system studies); United Technology (combustion research, and system studies); and Solar (combustion research).

The turbine industry recognizes that the chief technical barrier to coal-fired gas turbines (excluding highly cleaned coal-derived gaseous fuels or hydrotreated, refined coal liquids) is the greater concentration of impurities in coal as compared with clean distillate fuels. The industry recognizes potential advantage in the DOE/Fossil Energy program because lower cost coal fuels would, if cost-effective, offset the projected escalation of distillate prices and provide a hedge against supply uncertainties as well.

## HEAT ENGINES

Question #5: Please explain the role that these heat engines could play in the use of coal in the future and what its timing would be. What are the advantages of such systems over other power conversion systems? In what time frame would such systems be available if R&D is successful?

Answer: The program aims toward the substitution of coal-derived fuels for clean distillate fuels and natural gas in gas turbine and diesel engines by the late 1990s. Gas turbines are widely used (nearly 70 gigawatts) in utilities and industry. Their high efficiency, high combined cycle electrical/thermal ratio, and low cost offer major future growth opportunities for meeting future capacity shortfalls and cogeneration under PURPA regulations. Diesels are critically important to rail and waterway shipping. The present and future economic welfare of both power systems is being threatened by the price and availability uncertainties of distillate fuel. The DOE program is conducting the generic engineering research which would stimulate major private sector commercial development investments by the late 1990's.

## HEAT ENGINES

Question #6: Are such engines compatible with the use of coal in the railroad industry? Are you doing any research in this area? With regard to the railroad industry, would fluidized bed steam cycles be an alternative worth looking at?

Answer: Coal fueled diesel engines would be particularly compatible with the railroad industry, particularly those carriers who depend upon coal for a significant share of their revenues. Our diesel research holds long term promise for such applications. The railroads are themselves evaluating coal-derived hydrotreated liquid fuels for possibly nearer term solutions. Various coal-fired steam engines are also being considered as possible nearer-term answers to the railroad's fuel cost problem. The Burlington Northern Railroad Company and the Norfolk Southern Corporation have joined in a research program at the General Electric Company to study various concepts of coal-fired locomotives including steam engines. Previously, studies were conducted cooperatively by Burlington Northern, the Chessie System, Babcock and Wilcox, and the American Coal Enterprise Company on an advanced coal-fired steam locomotive (ACE program). Other private initiatives include a coal-fueled fluidized bed/steam design concept to power a modified diesel power plant by the Natural Steam Propulsion Company.

## UNDERGROUND COAL GASIFICATION

Question #1: Please review the potential economics of underground coal gasification and the extent of its potential uses. What is industry's opinion of this potential? Who in industry is or has been involved in this technology and what are they doing to commercialize it, if anything?

Answer: Earlier economic studies conducted by Gulf Corporation; Hammesfahr, Winter and Associates; Bechtel Group of Companies; Williams Brothers Engineering Company; and others, have shown very favorable potential economics for Underground Coal Gasification (UCG) in the most readily gasified coals to which DOE is familiar. These favorable economics (see chart below) result from an approximate 25 percent reduction in capital costs (as contrasted to surface gasification facilities) and the modular aspects of the process such that smaller facilities can be utilized rather than large expensive ones. One complete session of the Tenth Annual Underground Coal Gasification Symposium, August 12-14, 1984, has been dedicated to ascertain the current economic picture for UCG and to determine industries future involvement in the technology including the potential for commercialization.

| | Range of Recent Cost Studies for UCG-derived products |
|---|---|
| Medium-BTU gas | $1.75 - $3.50/MM BTU |
| Methanol | $ .60 - $ .75/gal |
| SNG | $5.50 - $7.50/MM BTU |

## UNDERGROUND COAL GASIFICATION

Question #2: What are the main environmental problems involved in this technology and what is being done to mitigate those problems?

Answer: The two major environmental problems that need to be further resolved before UCG can be readily commercialized are potential groundwater contamination and surface subsidence. Other impacts such as liquid effluents, gaseous emissions, surface water pollution, socioeconomic, etc., are minimal compared to other methods of recovering similar resources. Surface subsidence can be eliminated or minimized by proper selection of the resource being addressed. If the resource being recovered is such that subsidence will be a factor, surface restoration must be included in the site abandonment plans.

Potential groundwater contamination is the major environmental concern in UCG and the current DOE UCG program is addressing this problem. A major long-term effort is underway at former UCG test sites located near Hanna and Gillette (Hoe Creek), Wyoming, to ascertain residual levels of respective contamination, their movement within the surrounding aquifers and the development of restoration techniques if required. Delineation of the contamination levels and the impacted area at the site of the UCG experiment is likely to have generated the most impact at the end of FY 1984, and initial restoration approaches are to be launched in early FY 1985.

UNDERGROUND COAL GASIFICATION

Question #3: For historical purposes, please provide a recap of the tests that have been done in the program and of what significance those tests are with regard to the commercialization or environmental problems of the technology.

Answer: The attached table presents a chronology of the major field tests performed in recent times under the DOE UCG program (and its predecessor programs in the USBM and ERDA). The Hanna tests demonstrated reverse combustion linking and forward gasification of flat-lying subbituminous coal beds using air injection to produce a low heating value gas. The Hoe Creek tests investigated several options for gasifying subbituminous coals, including the use of steam and oxygen to produce a medium heating value gas, and the use of a deviated wellbore to provide a controllable link between process wells. The subsidence and groundwater contaminant generation experienced during some of these shallow tests yielded important site and design parameters for UCG. The Pricetown test explored the feasbility of producing a low heating value gas from deeply lying, thin seams of high swelling, high sulfur bituminous coals. The Rawlins tests demonstrated the viability of gasifying steeply-dipping subbituminous coal beds. The Centralia test investigated the feasibility of gasifying a high ash, subbituminous coal using directionally drilled wells and a new process ignition and control technique called Controlled Retracting Injection Point (CRIP).

## U.S. UCS FIELD TESTS

AIR INJECTION UNLESS OTHERWISE NOTED

| TEST # | YEAR | DURATION (DAYS) | QUALITY (BTU/SCF) | DRY GAS PRODUCTION $10^6$ SCF/DAY | TONS GASIFIED (TONS) |
|---|---|---|---|---|---|
| SPONSORED BY U.S. GOVERNMENT | | | | | |
| ● LETC, HANNA, WY | | | | | |
| HANNA 1 | 1973/74 | 180 | 126 | 1.6 | 4000 |
| HANNA 2-1 | 1975 | 38 | 152 | 1.7 | 1260 |
| HANNA 2-2 | 1975 | 25 | 175 | 8.5 | 2520 |
| HANNA 2-3 | 1976 | 38 | 138 | 12.0 | 4200 |
| HANNA 3 | 1977 | 38 | 130 | 10.0 | 2850 |
| HANNA 4 | 1977/79 | 24 | 133 | 8.3 | 1500 |
| ● LLL | | | | | |
| HOE CREEK 1 | 1976 | 11 | 102 | 1.2 | 129 |
| HOE CREEK 2 | 1977 | 58 | 108 | 3.3 | 2480 |
| HOE CREEK 3 (OXYGEN ONLY) | 1979 | 47 | 217 | 3.4 | 3950 |
| CENTRALIA (P.S. CRIP) | 1983 | 30 | 240 | 2.3 | 2100 |

## U.S. UCG FIELD TESTS (CONTINUED)

AIR INJECTION UNLESS OTHERWISE NOTED

| TEST # | YEAR | DURATION (DAYS) | QUALITY (BTU/SCF) | DRY GAS PRODUCTION $10^6$ SCF/DAY | TONS GASIFIED - (TONS) |
|---|---|---|---|---|---|
| (U.S. GOVT. CONT.) | | | | | |
| ● METC, PRICETOWN, WV | | | | | |
| PRICETOWN | 1979 | 12 | 127 | 3.4 | 350 |
| ● GULF/TRW, RAWLINS, WY | | | | | |
| RAWLINS 1 | 1979 | 30 | 150<br>250(OXYGEN) | 3.8 | 1020 |
| RAWLINS 2 (OXYGEN ONLY) | 1981 | 65 | 350 | 7.0-12 | 8600 |

## UNDERGROUND COAL GASIFICATION

| | |
|---|---|
| Question #4: | Please describe your contemplated program for a follow up to the Controlled Retracting Injection Point (CRIP) test for FY 1985. Are you expecting a substantial cost share from industry? If so, who are the interested parties? |
| Answer: | The entire UCG program is currently undergoing a critical review in the Spring of 1984 to determine where program funding can best be used to further the development of a UCG technology data base. Development of the CRIP technique is a small but important portion of that program. We are currently anticipating a proposal from WIDCo for a larger follow-up test, in 1985, based on the Tono CRIP test, perhaps at the $5,000,000 - $10,000,000 level with substantial cost-sharing by participants (TBD) with WIDCo. This is the only known industrial effort which may be requesting significant funding from DOE. |

## UNDERGROUND COAL GASIFICATION

Question #5: Have you selected a site for the gasification of Eastern bituminous coal? If not, how will it be selected? If so, where is it and why was it selected?

Answer: Forty sites recommended by the states of Ohio, Kentucky, and Illinois, have been ranked according to geologic and other factors seen providing DOE with optimum coal deposit conditions for the R&D studies of underground gasification of eastern bituminous coal. The higher ranked sites are located in Illinois and an announcement of Illinois' selection will be made in March 1984. The coal owners (AMAX Coal Company, Peabody Coal Company, and Coastal States Energy) of the sites have been contacted to ascertain interest in the project and the availability of the site(s). Internal corporate discussions are in progress and a corporate decision relative to participation in the project is anticipated during March.

## UNDERGROUND COAL GASIFICATION

Question #6: In the future, what activities do you expect to undertake in this program now that, in many cases, enough data seems to exist for commercialization?

Answer: The only new effort currently planned is a program to further develop UCG technology in swelling bituminous coals. A program has been planned and is in the early implementation stages (see Question #5).

Follow-on research on the CRIP technique will be done, but the exact type of work is in the process of being determined.

## MAGNETOHYDRODYNAMICS

Question #1: Please briefly describe for each of the pieces of the proposed scientific program what specific technical problems need to be solved and the timing required to solve them, assuming a reasonable progression in R&D results.

Answer: The critical technical problems and/or uncertainties to be resolved in the course of the MHD program fall into five general areas: the coal-fired combustor, the MHD channel, the superconducting magnet, seed regeneration, and system integration.

The critical coal-fired combustor problems are continuous slag rejection, electrical isolation, coal, seed and oxidant introduction at controlled rates, and plasma stability.

The MHD channel problems entail durability and electrical, thermal, chemical, and gas dynamic interaction phenomena.

In the superconducting magnet area, scaling issues and constructability problems must be addressed.

Seed regeneration processes must be studied both at the basic research and pilot plant levels to determine reaction kinetics, yields, and economics.

Systems integration activities are required to resolve the problems inherent in the dynamic control of a combined cycle power plant before such a plant can be constructed.

It is expected that an adequate information base in all of the critical technical problem areas will be developed by January 1986 to permit the use of the research results in the final engineering design of an integrated test facility.

MAGNETOHYDRODYNAMICS

Question #2: Please describe the extent and the use of the mobile diagnostic instrumentation laboratory and how it was developed.

Answer: Activities at Mississippi State University's (MSU) MHD Energy Center have focused on developing instrumentation and diagnostic equipment specifically tailored to MHD system requirements. These instruments include a two color pyrometer and sodium line reversal system for gas temperature measurement, a laser velocimeter for gas velocity measurements, and other non-intrusive optical devices for the determination of the properties and composition of coal derived, particle laden, high temperature gases. Although a few of these instruments have been used in limited laboratory applications, considerable development has been required to adapt them to the heavily particulate-laden plasma generated in coal-fired MHD systems and to reliable operation in fringe magnetic fields.

MSU has also been developing techniques for packaging the above-described instruments into rugged and automated configurations so that they can be used in both experimental field installations and in the actual utility power plant environment.

One of MSU's major activities for 1984 is the design, construction, and deployment of a mobile diagnostic laboratory incorporating these instruments. This mobile laboratory is expected to be operational by September 30, 1984. It will enable them to meet their instrumentation support commitments at the CDIF, CFFF, and ANL more economically and efficiently than was possible with the independent shipment and set up of instruments at each facility.

MAGNETOHYDRODYNAMICS

Question #3: Please explain your preliminary estimate of the timing and cost of the Phase II or Advanced Research Integration Facility that you request.

Answer: Assuming prompt agreement between DOE and the industrial cost-sharing participants, conceptual design of the integrated MHD facility could be initiated in FY 1984. Engineering design, component and subsystem design, and facility construction would proceed through FY 1989 and long term operation would commence in FY 1990. The overall program cost, including public and private industry cost-sharing, is estimated at about $180,000,000.

Question #4: To what extent has this concept been discussed with the industry involved? What is their interest? Have they given any indication of their willingness to cost share in the earliest stages of this program?

Answer: Discussions pertaining to the cost-shared integrated facility concept were initiated in early February 1984. Preliminary indications suggest that the private sector may be willing to offer some cost sharing, but no commitments have been made at this time.

Question #5: How does this advanced research program differ from the original concept of the MHD community of a retrofit system? What more advanced technology would be involved in your program that would not be involved in the retrofit program? If your advanced research program were pursued, would a retrofit program after that make any sense, or would a new stand alone facility or larger test be more practical?

Answer: The proposed 80 Mw thermal integrated MHD facility is believed to be an essential step toward the ultimate commercialization of the technology. The construction of a retrofit system or a new stand alone plant of 200-500 Mw thermal size by industry would be viewed as the logical follow-on step.

SURFACE COAL GASIFICATION

Question #1: Please explain what information will be gathered from the Great Plains Coal Gasification Project and how it will be useful to the DOE program in general.

Answer: Information to be gathered from the Great Plains Coal Gasification Plant (GPCGP) Project will include U.S.-based experience with respect to siting, design, construction, start-up and operations, environmental effects, socioeconomic impacts, and cost-related matters. Specifically, the GPCGP offers the opportunity to acquire essential technological data in the following areas:

- Plant Performance - Verification of performance of key operational components and "on-stream" time.
- Site Related Experience - Specification of construction materials and operating methods for future facilities.
- Primary Plant Systems - Development of information on such areas as zero effluent discharge, sulfur removal, and waste water treatment.
- System Integration - Experience in operating enclosed coal handling facilities, removing or adding spare systems, and operating emergency shut down systems.

In addition to the technological information to be gathered from the GPCGP, an experience base will be established in areas such as:

- Costs - Verification of capital costs, including labor, materials, components, and instrumentation. Development of data on operational, maintenance and raw material costs.

- Schedules - Development of schedule data associated with the planning, design/procurement, construction, initial operation and continual operation of the facility.

- Management - Development of information associated with project planning and control, licensing, permitting, regulatory compliance, liability risk and financing terms. Validation of data on tax treatment, technology transfer, and price controls.

- Product Characteristics - Development of data on product quality, product slate capabilities and markets, and by-product utilization.

- Environment, Health and Safety - Validation of approaches to ecology monitoring, pollutant fate and reclamation; mitigation and control approaches; environmental compliance including air quality, water quality, and solid waste control; establishment of data on public and occupational health and safety including medical surveillance, industrial hygiene, epidemiology and toxicology.

- Community Impacts - Validation of socioeconomic impact predictions and infrastructure requirements; impact mitigation process; and requirements for replicating that process.

This information is fundamental if the Department of Energy, policymakers and regulatory agencies are to make well-informed, prudent decisions in the future regarding synthetic fuel facilities. If future synthetic fuel plants are required — and the National Energy Policy Plan projects an increasing need for synthetic fuels as we move into the 21st Century — these plants will operate more efficiently, more economically, and with greater public confidence because of the lessons we stand to gain from Great Plains.

## SURFACE COAL GASIFICATION

Question #2: Please provide some information on the current status of all gasifiers which are offered commercially or which have been developed to some extent by DOE and others. The purpose of this material should be to identify, in a reasonable fashion, those areas where no additional development is necessary and those areas where additional development to reach commercialization might be required. It would be useful to know the type of gasifier involved, its largest size, the type of coal it can operate on, the type of product it produces, and shortcomings or advantages of the technology.

Answer: The technology of coal gasification is addressed most often by a particular gasifier configuration rather than by a product resulting from the process. Initially this focus was created by the limitations of older technologies (before 1950) that:

- Greatly restricted their application in the use of the heterogenous, widely scattered coal resources in the United States and the world.
- Significantly reduced their ability to be used in facilities of the scale (output capacity) performance efficiences and environmental limitations planned.
- Restricted the options available for their use (generally low-Btu gas for local of nearby consumption) and which eliminated their consideration for a wide spectrum of energy producing applications and product production.

However, in the last 25 years significant amounts of time and money have been directed to the development of advanced gasifiers by the Government as well as the industrial sector in the National as well as the international community. These efforts have resulted in significant advances in gasifier technology. As shown in attached

Table I, at least 20-24 gasifiers at some stage in the development cycle (i.e., bench scale, PDU, pilot plant, demonstration facility) have been studied in the technology development projects supported by the DOE and its precedessor agencies. From this work, eight or more concepts have been advanced through the proof-of-concept stage and are logical candidates for any subsequent commercialization effort by the industrial sector.

The international community also is developing a number of different experimental gasifiers. As shown in attached Table II, as many as five countries have development programs in progress. As a minimum, these programs are continuing the development of eleven gasifier concepts. In addition, the U.S. industrial sector is supporting the continued development of several gasifier concepts at the demonstration stage. These projects and their characteristics are listed in attached Table III.

As a result of these past and ongoing efforts there are more than eleven gasifier concepts developed to the stage that they can be demonstrated or commercialized. These concepts offer a full range of operational as well as feedstock capabilities and as shown in Table IV these gasifiers (shown at the pilot plant and demonstration stage of development) have the ability to convert coal into the full range of gaseous and liquid fuels as well chemical feedstocks.

As noted earlier, the gasification process is most commonly associated with the name of a specific reactor. What often is forgotten is that the reactor representing only about 10-15 percent of the total cost of a gasification facility is but one step in a system consisting of a variety of unit operations. The complexity of these systems can vary from a few comparatively simple operations resulting in a single product (e.g., low/medium-Btu gas) to extremely complex chemical processing plants capable of producing a variety of products. However, consistent with the availability and commercial use of gasification technology for over a hundred years is the availability and use of the full gasification system. As shown in attached Table V, these systems do exist and are operating on a world-wide basis. An analysis of the information given in Table V used to prepare Table VI shows that currently there are approximately 300 gasifiers representing seven different manufacturers being used in processes that will produce:

- Low-Btu gas for industrial uses
- Medium-Btu gas for town gas application
- Syngas for the production of ammonia, methanol and/or hydrogen
- Syngas for indirect liquefaction processes

Based upon the above considerations, the R&D program in Surface Gasification has been formulated and does reflect both the maturity of the technology and the activities underway in the industrial as well as the international community. It's activities are selected and performed in accordance with the different responsibilities given to the Government as compared to those assigned to industry. Projects and studies are selected that are high risk and which have the potential to:

- Contribute significantly in advancing the state-of-the-art of gasification so that it is fully responsive to the needs of a continuosly changing market.
- To generate data needed to design, modify, apply and upgrade the technology.
- To insure continued transfer of technology to industry so that they can complete their responsibilities in selection and implementation of any advances made.

Research and development efforts are focused on the acquisition of data leading to a fuller understanding of the gasification process itself and the functional links between that process and the operational parameters that will permit:

- Advancing the state-of-the-art of the coal gasifier so that its technology remains current with those advances being made in associated fields, (e.g., establish performance with new sophisticated feedstocks as micropulverized and deep cleaned coal) and it has the ability to be responsive to any associated processing system that is designed to accommodate a changing market for fuels, (e.g., hydrogen, methanol, minimally processed liquids, etc.).
- Comparison with any new concepts that appear to be "breakthroughs" or have the potential to produce significant improvements in the technology.
- Projection of gasifier performance in a manner that would permit system optimization and appropriate selection of downstream processing components.

- Confirmation of the chemistry, kinetics, and thermodynamics of the gasification process required to confirm, extend, and apply sophisticated models and modeling codes for fixed, fluidized, and entrained-bed systems.
- Commercialization of the technology in a environmentally acceptable manner.

These data will be acquired by incorporating into the R&D program efforts that:

- Continue to look for new chemistries and technological advances that have the potential in improve, combine, or eliminate the unit operations required for feedstock preparation, gas separation, cleanup, conversion, product manufacture, etc.
- Introduce and develop those materials and component concepts that have the ability to significantly reduce the capital cost of these facilities, increase system reliability to minimize down time (i.e., increase system availability) and increase operating performance.
- Continue the study of those environmenally oriented parameters and processes that will insure that the conversion of coal through gasification has a minimum environmental impact.
- Examine new approaches and/or variations in the capabilities of the process and/or the markets that provide new/unusual opportunities for the application of the technology.

The data obtained from such activities are particularly suited to be the objectives of a research and development program focused on long range, high risk efforts that would not normally be pursued by industry, but which are essential for the continued advancement of the state-of-the-art and increased capability of the technology to meet changing market demands.

TABLE I
SURFACE COAL GASIFICATION
PDU, PILOT PLANT, DEMONSTRATION COMMERCIAL PROJECTS

- DOE/FOSSIL ENERGY PROGRAM

| Process | Facility Type | Contractor | Plant Location | Bed Type | Coal Type | Plant or Design Capacity TPH [1] | Operating Pressure PSI | Product Gas Type | Status |
|---|---|---|---|---|---|---|---|---|---|
| Agglomerating Burner | PDU | Battelle Columbus | Columbus, OH | Fluid Bed | All* | 1 | 125 | High | Terminated - Evaluation Indicated Low Potential |
| Catalytic Gasification | PDU | Exxon | Baytown, TX | Fluid Bed | All | 0.04 | 500 | High Syngas | Technology Established PDU - Transferred to Industry |
| Fast Fluid Bed | PDU | HRI | Trenton, NJ | Fluid Bed | All | 0.3 | 150 | Low | Terminated - Evaluation Indicated Low Potential |
| High Mass Flux | PDU | Bell Aerospace | Buffalo, NY | Entrained | All | 10 |  | High | Deactivated - Facility Being Used For Basic Studies |
| Hydrogasification - Short Residence Time | PDU | Rockwell Int'l | Canoga Park, CA | Entrained | All | 0.75 | 1000-1500 | High | Advanced Concept Under Development |
| Molten Salt | PDU | Rockwell Int'l | Canago Park, CA | Molten Bath | All | 1 | 15-300 | Low Syngas | Gasifier Developed Thru PDU Level - Available to Industry |
| Pressurized Fluidized Bed | PDU | Westing-house | Madison, PA | Fluid Bed | All | 0.6 | 150-225 | Low & Medium | Gasifier Developed Transfer to Industry in Progress |
| Slagging Fixed Bed | PDU | GFETC | Grand Forks, ND | Fixed | Western | 0.75 | 400 | High | Gasifier Developed - Facility Used in Support Work |
| Stirred Fixed Bed | PDU | METC | Morgan-town, WV | Fixed | All | 0.75 | 275 | Low | Gasifier Developed - . Facility Used in Support Work |

[1] Ton per hour

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TABLE I (CON'T)
SURFACE COAL GASIFICATION
PDU, PILOT PLANT, DEMONSTRATION COMMERCIAL PROJECTS

● DOE/FOSSIL ENERGY PROGRAM

| Process | Facility Type | Contractor | Plant Location | Bed Type | Coal Type | Plant or Design Capacity TPH [1] | Operating Pressure PSI | Product Gas Type | Status |
|---|---|---|---|---|---|---|---|---|---|
| Tri-Gas | PDU | BCR | Monroeville, PA | Fluid Bed | All | 0.05 | 300 | Low | Terminated - Evaluation Indicated Low Potential |
| Atmospheric Entrained Bed | Pilot Plant | Combustion Engineering | Windsor, CT | Entrained | All | 5 | 15 | Low | Gasifier Developed Available to Industry |
| BI-GAS | Pilot Plant | Stearns-Roger | Homer City, PA | Entrained | All | 5 | 1500 | High | Developmental Operation |
| $CO_2$ Acceptor | Pilot Plant | Conoco | Rapid City, SD | Fluid Bed | Lignite & Sub-Bit. | 3 | 150 | High Syngas | Gasifier Developed - Available to Industry |
| Hygas | Pilot Plant | IGT | Chicago, IL | Fluid Bed | All* | 3 | 500-1000 | High | Gasifier Developed - Available to Industry |
| Peat Gasification | Pilot Plant | IGT | Chicago, IL | Fluid Bed | Peat | 3.0 | 500 | High Syngas | Technology Developed at Pilot Plant Level |
| Pressurized Entrained Bed Pilot Plant | Pilot Plant | Mt. Fuel Resources, Inc. | Salt Lake City, Utah | Entrained | All | 1.25 | 150 | Low | Developmental Operation |
| Steam-Iron | Pilot Plant | IGT | Chicago, IL | Fluid Bed | All* | 2.2 | 1000 | Medium | Terminated - Low Potential |
| Synthane | Pilot Plant | C-E Lummus | Bruceton, PA | Fluid Bed | All* | 3 | 1000 | High | Terminated - Low Potential |

[1] Ton per hour

TABLE I (CON'T)

SURFACE COAL GASIFICATION
PDU, PILOT PLANT, DEMONSTRATION COMMERCIAL PROJECTS

- **DOE/FOSSIL ENERGY PROGRAM**

| Process | Facility Type | Contractor | Plant Location | Bed Type | Coal Type | Plant or Design Capacity TPH [1] | Operating Pressure PSI | Product Gas Type | Status |
|---|---|---|---|---|---|---|---|---|---|
| U-Gas | Pilot Plant | IGT | Chicago, IL | Fluid Bed | All | 1 | 15-60 | Medium Syngas | Gasifier Developed Available to Industry |
| Stoic | Demo Plant | U of MN | Duluth, MN | Fixed | Non-Caking | 3 | 15 | Low | Industrial Operation |
| Wellman Galusha | Demo Plant | Bureau of Mines | Minneapolis, MN | Fixed | Non-Caking | 1.5 | 15 | Low | Operation in Support of Experimental Studies |
| Wellman Galusha | Demo Plant | Acurex-Herotherm/ Glen Gary | York, PA | Fixed | Non-Caking | 1.0 | 15 | Low | Developed Technology Industrial Operation |
| BGC/Lurgi Slagging Gasifier | Demo Plant | Conoco | Noble Co., OH | Fixed | Non-Caking | 1,270 TPD | 450 | High | Technology Developed Available to Industry |
| COGAS | Demo Plant | IL Coal Gas Group | Perry Co., IL | Fluid | All | 2,210 TPD | 15-60 | High Plus Liquids | Technology Developed Available to Industry |

[1] Ton per hour

C

TABLE II
SURFACE COAL GASIFICATION
PDU, PILOT PLANT DEMONSTRATION PLANT PROJECTS

● INTERNATIONAL PROJECTS

| Country | Process | Plant Capacity Metric TPD | Location | Proposed Commercial Site | Proposed Commercial Capacity MTPP | Status |
|---|---|---|---|---|---|---|
| Federal Republic of Germany (FRG) | Shell Koppers | 150 | Hamberg | --- | ---- | Earlier Commercial Plans on Hold or Abandoned |
| FRG | High Temperature Winkler | 24 | Frecher | Huerth-Berhenrath FRG | 6700 | No Government Support Rheinbraun Constructing Commercial Facility |
| FRG | Saar Berg-Otto | 264 | Volklinger-Furstenhausen | --- | ---- | Government Support Ending; No Commercial Plans Announced |
| FRG | RAG/RCH Texaco | 144 | Oberhausen Holten | Cool Water | | Government Interested in Commercial Project in FRG |
| FRG | RUHR-100 High-Pressure Lurgi | 135 | Dorsten | --- | ---- | Government Support Ending; No Commercial Plans |
| FRG | KGN Fixed-Bed | 2 | Huckelhoven | Huckelhoven | 5500 | State Government of Nordrhein West Falia To Fund Project Thru Demo |
| FRG | Kloechner Molten Iron | 240 | Ruhr Region | --- | 1900 | Government Interested in Supporting Commercial Demo |

D

TABLE II (CON'T)
SURFACE COAL GASIFICATION
PDU, PILOT PLAN T DEMONSTRATION PLANT PROJECTS

● INTERNATIONAL PROJECTS

| Country | Process | Plant Capacity MTPD | Location | Proposed Commercial Site | Proposed Commercial Capacity MTPP | Status |
|---|---|---|---|---|---|---|
| FRG | Partial Gasification | 360 | Stockum | Gersteinwelke | 5500 | Government Funding Ending Commercial Prospects Low |
| FRG | Steag/Lurgi Combined Cycle | --- | --- | Lunen | 1700 | Commercial Facility Shut Down for Economic Reasons |
| Great Britain | British Gas Slagging Lurgi | 800 | Westfield, Scotland | --- | ---- | British Gas Trying to Find Sponsor |
| India |  | 144 | Trichy | Tiruchiradalli |  | Demonstration Unit Undergoing Testing |
| Japan | Sumitomi Molten Iron | 60 | Kashima | --- | ---- | Future Plans Call for Construction of Demo |
| Japan | Mitsui M-Gas |  | Kitakyusha | --- | ---- | Early Phases of Pilot Plant Testing |
| Japan | Coal Mining Research Combined Cycle | 40 | Yubari, Hokkaido | --- | 1000 | Pilot Plant Still in Testing Phase |
| Soviet Union | Power Engineering High Speed Pyrolysis -Fixed | 100-200 | Kalingrad | Kansk Achinsk | 175 MT/HR | Demo Plant in Construction |

E

# TABLE III
## SURFACE COAL GASIFICATION
## PILOT PLANT, DEMONSTRATION, COMMERCIAL PROJECTS

- **INDUSTRIAL/COMMERCIAL PROJECTS**

| Process | Facility Type | Contractor | Plant Location | Bed Type | Coal Type | Plant or Design Capacity TPH | Operating Pressure PSI | Product Gas Type | Status |
|---|---|---|---|---|---|---|---|---|---|
| Ammonia From Coal/Texaco | Pilot Plant | TVA | Muscle Shoals, Ala. | Entrained | All | 225 TPD | 510 | Synthesis | Shakedown and Startup Operations |
| Kiln Gas | Demo | Allis Chalmers | Wood River, Ill. | Rotary | All | 675 TPD | 120 | Low | Construction in Progress |
| Cool Water/Texaco | Demo | EPRI | Daggett, Calif. | Entrained | All | 1000 TPD | 600 | Medium | Construction in Progress, Startup 2/84 |
| Great Plains Gasification Project/Lurgi | Commercial | Great Plains Gasification Associates | Mercer County, N.D. | Fixed | Lignite & Sub-Bit. | 14000 TPD | 430 | | Construction 50% Complete |
| Chemicals From Coal/Texaco | Demo Plant | Tennessee Eastman | Kingsport, Tenn. | Entrained | All | 900 TPD | | Syngas | Construction in Progress -- Over 50% Complete |
| Chemicals From Coal/Texaco | Pilot Plant | Dow Chemical Co. | Plaquemine, La. | Entrained | All | 200 TPD | | Synthesis | In Operation |

F

FIGURE IV
Correlation of Gasifiers
By Stage of Development and Product Gas

| State of Development<br>Product | Process Development Unit | Pilot Plant | Demonstration Plant | Commercial Facility |
|---|---|---|---|---|
| Low-BTU Gas | S - Molten Salt | E - Combustion Engineering | | M - Stoic<br>M - Wellman Galusha<br>F - Winkler |
| Medium-BTU and Synthesis Gas | F - Catalytic<br>E - Mountain Fuel | F - $CO_2$ Acceptor<br>E - Shell | F - Westinghouse<br>F - U-Gas<br>M - BGC/Lurgi Slagger<br>F - COGAS<br>E - Texaco<br>S - Kiln Gas<br>F - High Temp Winkler<br>S - Saar-Berg OTTO | M - Lurgi<br>E - Kt |
| High-BTU Gas | E - Flash Hydropyrolysis | F - HYGAS<br>E - BIGAS<br>M - Lurgi Ruhr-100 | | M - Lurgi |

M = Moving Bed    F = Fluidized Bed    E = Enhanced Bed    S = Special Type

Foreign Technologies Underlined

## TABLE V

## LIST OF FOREIGN COAL GASIFICATION FACILITIES*

*List contains facilities which are currently operating or which have been shut down for less than five years

## LIST OF FOREIGN COAL GASIFICATION FACILITIES

| Location | Gasifier Type & Number | Dates | Coal Type | Product Gas (Application) | Capacity per Unit |
|---|---|---|---|---|---|
| **Bulgaria** | | | | | |
| Dimitroffgrad | Winkler<br>4 | 1931 to Present | | Medium-Btu | 16.1 MMSCFD |
| Stara Zagora | Winkler<br>5 | 1962 to Present | | Medium-Btu | 27 MMSCFD |
| **Czechoslovakia** | | | | | |
| Chomutov | Woodall-Duckham<br>14 | ? to Present | Lignite | Low-Btu (Metal Works) | Approx. 2 MMSCFD |
| **East Germany** | | | | | |
| Schwarze Pumpe | Lurgi<br>24 | 1966 to 1980 | Lignite | Medium-Btu (Town Gas) | 24 MMSCFD |
| Schwarze Pumpe | Winkler<br>6 | 1950 to Present | Lignite | Low-Btu | 58 MMSCFD |
| Bohlen | Winkler<br>3 | 1938 to Present | Lignite/Coke | Syngas (Hydrogen) | 27 MMSCFD |
| Bohlen | Lurgi<br>10 | 1940/43** to ? | Lignite | Medium-Btu (Town Gas) | Approx. 2.5 MMSCFD |
| Zeitz | Winkler<br>3 | 1941 to Present | Lignite | Syngas (Hydrogen) | 20 MMSCFD |
| Karl-Marx Stadt | Koppers-Totzek<br>2 | 1966 to Present | Oil Residue (Coke) | Syngas (Ammonia) | 13.4 MMSCFD |
| **West Germany** | | | | | |
| Luenen | Lurgi<br>5 | 1969/70 to 1979 | Subbitum. | Low-Btu (Gas Turbine) | Approx. 65 MMSCFD |
| **Great Britain** | | | | | |
| Westfield | Lurgi<br>5 | 1960/62 to 1974 | Bitum./ Subbitum. | Medium-Btu (Town Gas) | 9 MMSCFD |
| **Greece** | | | | | |
| Ptolemais | Koppers-Totzek<br>6 | 1959/69/70 to Present | Lignite | Syngas (Ammonia) | 6 to 9 MMSCFD |

## LIST OF FOREIGN COAL GASIFICATION FACILITIES

| Location | Gasifier Type & Number | Dates | Coal Type | Product Gas (Application) | Capacity per Unit |
|---|---|---|---|---|---|
| **India** | | | | | |
| ? | Wellman-Galusha<br>6 | | | | |
| Ramagundam | Koppers-Totzek (4 headed)<br>3 | 1980 to Present | | Syngas (Ammonia) | 19 MMSCFD |
| Korba | Koppers-Totzek (4 headed)<br>3 | 1972* Construction Close to Completion | | Syngas (Ammonia) | 19 MMSCFD |
| Talcher | Koppers-Totzek (4 headed)<br>3 | 1980 to Present | | Syngas (Ammonia) | 19 MMSCFD |
| Jealgora | Lurgi<br>1 | 1961 to Present | Various | | |
| Asansol | Riley-Morgan<br>2 | 1952/68 to Present | Bitum. | | |
| Madras | Winkler<br>3 | 1961 to 1979 | Lignite (now oil) | Syngas (Ammonia) | 17.8 MMSCFD |
| **Portugal** | | | | | |
| Lisbon | Koppers-Totzek | 1956 to Present | Lignite/ Anthracite | Syngas (Ammonia) | Approx. 4 MMSCFD |
| **South Africa** | | | | | |
| Sasolburg (Sasol I) | Lurgi<br>17 | 1954/58/ 66/73/80 to Present | Subbitum. | Syngas (Liquid Hydrocarbons), Ammonia, Fuel Gas | 33 MMSCFD to 100 |
| Secunda (Sasol II) | Lurgi<br>36 | 1979/80 to Present | Subbitum. | Syngas (Liquid Hydrocarbons) | 33 MMSCFD |
| Modderfontein (Johannesburg) | Koppers-Totzek<br>6 | 1974 to Present | Bitum. | Syngas (Ammonia) | Approx. 14 MMSCFD |
| Vaal Potteries | Wellman-Galusha<br>1 | 1955 to Present | | Low-Btu (Furnace) | |
| Union Steel | Wellman-Galusha<br>7 | 1951 to Present | | Low-Btu (Metal Works) | |
| Rand Brick | Wellman-Galusha<br>1 | 1949 to Present | | Low-Btu (Brick-Kiln) | |

## LIST OF FOREIGN COAL GASIFICATION FACILITIES

| Location | Gasifier Type & Number | Dates | Coal Type | Product Gas (Application) | Capacity per Unit |
|---|---|---|---|---|---|
| South Africa (Cont'd) | | | | | |
| Scaw Metals | Wellman-Galusha<br>1 | 1955 to Present | | Low-Btu (Metal Works) | |
| Lydenberg | Stoic<br>1 | 1976 to Present | Bitum. | Low-Btu (Metal Works) | |
| Driefontein | Stoic<br>1 | 1973 to Present | Bitum. | Low-Btu (Brick Kiln) | |
| Pretoria | Riley-Morgan<br>7 | 1933/41 to Present | Bitum. | Low-Btu (Metal Works) | Approx. 2 MMSCFD |
| Dundee | Riley-Morgan<br>2 | 1950 to Present | Bitum. | Low-Btu (Glass Works) | Approx. 2 MMSCFD |
| Springs | Woodall-Duckham<br>2 | ? to Present | Bitum. | Low-Btu | |
| Meyerton | Woodall-Duckham<br>1 | ? to Present | Bitum. | Low-Btu (Furnace) | |
| Johannesburg | Woodall-Duckham<br>2 | ? to Present | Bitum. | Low-Btu (Steel Works) | |
| Stewarts & Lloyds | Woodall-Duckham | ? to Present | Bitum. | Low-Btu (Steel Works) | |
| Escault | Woodall-Duckham<br>3 | ? to Present | Bitum. | Low-Btu (Furnace) | |
| Mandini | Woodall-Duckham<br>2 | ? to Present | Bitum | Low-Btu | |
| Driefontein | Woodall-Duckham<br>2 | ? to Present | Bitum. | | |
| Vereenigning | Woodall-Duckham<br>3 | ? to Present | Bitum. | Low-Btu (Refractory Works) | |
| Stewarts & Lloyds | Wellman-Incandescent | ? to Present | Bitum. | Low-Btu (Steel Works) | |
| Cullinan | Wellman-Incandescent<br>4 | 1964/65/73 to Present | Bitum. | Low-Btu (?) (Refractory Works) | |
| Scaw Metals | Wellman-Incandescent<br>5 | 1963/68/75 to Present | Bitum. | Low-Btu (?) (Steel Works) | |
| Johannesburg | Wellman-Incandescent<br>6 | 1963/68/75 to Present | Bitum. | Low-Btu (?) (Metals Works) | |
| Alusaf | Wellman-Incandescent<br>6 | 1978 to Present | Bitum. | Low-Btu (?) (Metal Works) | |

K

## LIST OF FOREIGN COAL GASIFICATION FACILITIES

| Location | Gasifier Type & Number | Dates | Coal Type | Product Gas (Application) | Capacity per Unit |
|---|---|---|---|---|---|
| **South Africa** (Cont'd) | | | | | |
| Grootfontein | Wellman-Incandescent 1 | 1970 to Present | Bitum. | Low-Btu (?) (Metal Works) | |
| South Cross Steel | Wellman-Incandescent 4 | 1968/76/80 to Present | Bitum. | Low-Btu (?) (Steel Works) | |
| Highveld Steel | Wellman-Incandescent 6 | 1968/76 to Present | Bitum. | Low-Btu (?) (Steel Works) | |
| USCO | Wellman-Incandescent | 1973 to Present | Bitum. | Low-Btu (?) (Steel Works) | |
| Saiccor | Wellman-Incandescent | 1973 to Present | Bitum. | Low-Btu (?) (Paper Works) | |
| Union Steel | Wellman-Incandescent 5 | 1965/68 to Present | | Low-Btu (?) (Steel Works) | |
| Consolidated Glass | Wellman-Incandescent | 1967 to Present | | Low-Btu (?) (Glass Works) | |
| **Thailand** | | | | | |
| Lampang | Koppers-Totzek 5 | 1963/66 to | Lignite | Syngas (Ammonia) | Approx. 10 MMSCFD |
| **Turkey** | | | | | |
| Kutahya | Koppers-Totzek 4 | 1966 to Present | Lignite | Syngas (Ammonia) | Approx. 9 MMSCFD |
| Kutahya | Winkler 2 | 1959 to Present | Lignite | Syngas (Ammonia) | Approx. 9 MMSCFD |
| Istanbul | Woodall-Duckham 1 | ? | Lignite | | |
| **U.S.S.R.** | | | | | |
| Salawad | Winkler 7 | 1950 to Present | | Medium-Btu | 21 MMSCFD |
| Baschkirien | Winkler 4 | 1950 to Present | | Medium-Btu | 57 MMSCFD |

## LIST OF FOREIGN COAL GASIFICATION FACILITIES

| Location | Gasifier Type & Number | Dates | Coal Type | Product Gas (Application) | Capacity per Unit |
|---|---|---|---|---|---|
| **Yugoslavia** | | | | | |
| Jendinjenja | Wellman-Galusha<br>1 | | | | |
| Gorazde | Winkler<br>1 | 1952 to Present | Subbitum. | Syngas (Ammonia) | 6.3 MMSCFD |
| Kosovo | Lurgi<br>6 | ? to Present | Lignite | Syngas (Ammonia) | 11.2 MMSCFD |
| **Zambia** | | | | | |
| Kafue | Koppers-Totzek<br>4 | 1967/74/75 to Present | Bitum. | Syngas (Ammonia Methanol) | Approx. 9 MMSCFD |
| | | **Under Construction/Engineering Design** | | | |
| **Brazil** | | | | | |
| San Jeronimo | Koppers-Totzek<br>2 | 1984 | Subbitum. | | Approx. 34 MMSCFD |
| Campo Largo | Carbogas-Pentagano | 1980 | Subbitum. | Low Btu? (Fuel Gas) | 3 MMSCFD |
| **China** | | | | | |
| Peking | Lurgi<br>4 | 1978 (order date) | Semi-Anthracite | Syngas (Ammonia) | Approx. 30 MMSCFD |
| **Poland** | | | | | |
| Katowice | Koppers-Totzek<br>3 | 1982/83 | Subbitum. | Med. Btu (Fuel Gas) | 35 MMSCFD |
| **South Africa** | | | | | |
| Secunda (SASOL III) | Lurgi<br>36 | 1984 | Subbitum. | Syngas (Liquid Hydrocarbons) | 33 MMSCFD |

## TABLE VI

## INTERNATIONAL APPLICATION OF COAL GASIFICATION SYSTEMS

| GASIFIER TYPE | PRODUCT/APPLICATION | NUMBER OF SYSTEMS | NUMBER OF GASIFIERS |
|---|---|---|---|
| Koppers-Totzek | Medium-Btu Fuel Gas | 1 | 3 |
| | Syngas to Ammonia | 10 | 37 |
| | Syngas to Methanol | 1 | 4 |
| Lurgi | Low-Btu Combined Cycle | 1 | 5 |
| | Medium-Btu Fuel Gas | 4 | 40 |
| | Syngas to Ammonia | 2 | 10 |
| | Syngas to Liquids | 2 | 53 |
| Riley-Morgen | Low-Btu Fuel Gas | 3 | 11 |
| Stoic | Low-Btu Fuel Gas | 2 | 2 |
| Wellman-Incandescent | Low-Btu Fuel Gas | 12 | 49 |
| Winkler | Low-Btu Fuel Gas | 5 | 16 |
| | Medium-Btu Fuel Gas | 6 | 27 |
| | Syngas to Ammonia | 3 | 6 |
| | Syngas to Hydrogen | 2 | 6 |
| Woodall-Duckham | Low-Btu Fuel Gas | 10 | 32 |

## SURFACE COAL GASIFICATION

Question #3: Please explain what the current plan is for using the funds appropriated for the Homer City pilot plant.

Answer: In response to Congressional direction, the DOE has submitted to Congress a plan for continued use of the facility within the available appropriated funds (i.e. $6,000,000 of FY 1984 monies). The basic approach being proposed for a continued gasification program at the Homer City facility will be to solicit proposals from industry to use the pilot plant for a Fossil Energy related project. The procurement will be a two-phase effort consisting of:

- A first phase that will provide support for multiple awards to perform a study that defines the best use for follow-on activities at the pilot plant. These studies must be completed within three months from the time the contract is awarded and must be performed by a firm or group that has the experience, capability and stated intention to use the facility if selected for Phase II. The study results will represent the basis for decision to proceed to the second phase.

- A second phase in which the winner of the first phase will initiate a cost shared program to modify and operate the facility. This program must be related to the gasification or related treatment of coal or other fossil fuels. The data to be generated must be relevant to the DOE program. The Government's contribution will be limited to $5,700,000 for a two-year program.

## SURFACE COAL GASIFICATION

Question #4: What are the major areas in gasification that still need to be investigated in order to provide a basis for a viable gasification industry?

Answer: The research and development program in Surface Coal Gasification should reflect both the maturity of the technology as well as the activities underway in the industrial and international community. It's activities are selected and performed in accordance with the different responsibilities given to the Government as compared to those assigned to industry.

Research and development efforts are now focused on the acquisition of data leading to a fully understanding of the gasification process itself and the functional links between that process and the operational parameters that will permit:

- Advancing the state-of-the-art of the coal gasifier so that its technology remains current with those advances being made in associated fields, (e.g., establish performance with new sophisticated feedstocks as micropulverized and deep cleaned coal) and it has the ability to be responsive to any associated processing system that is designed to accommodate a changing market for fuels, (e.g., hydrogen, methanol, minimally processed liquids, etc.).

- Comparison with any new concepts that appear to be "breakthroughs" or have the potential to produce significant improvements in the technology.

- Projection of gasifier performance in a manner that would permit system optimization and appropriate selection of downstream processing components.

- Confirmation of the chemistry, kinetics, and thermodynamics of the gasification process required to confirm, extend, and apply sophisticated models and modeling codes for fixed, fluidized, and entrained-bed systems.

- Commercialization of the technology in a environmentally acceptable manner.

These data will be acquired by incorporating into the R&D program efforts that:

- Continue to look for new chemistries and technological advances that have the potential in improve, combine, or eliminate the unit operations required for feedstock preparation, gas separation, cleanup, conversion, product manufacture, etc.

- Introduce and develop those materials and component concepts that have the ability to significantly reduce the capital cost of these facilities, increase system reliability to minimize down time (i.e., increase system availability) and increase operating performance.

- Continue the study of those environmenally oriented parameters and processes that will insure that the conversion of coal through gasification has a minimum environmental impact.

- Examine new approaches and/or variations in the capabilities of the process and/or the markets that provide new/unusual opportunities for the application of the technology.

The data obtained from such activities are particularly suited to be the objectives of a research and development program focused on long range, high risk efforts that would not normally be pursued by industry, but which are essential for the continued advancement of the state-of-the-art and increased capability of the technology to meet changing market demands.

## SURFACE COAL GASIFICATION

Question #5: Please describe the Beacon Process and the work being done on it in FY 1984. Of what potential is this process?

Answer: The Beacon Process is a unique concept which starts with a low-Btu gas derived from coal and upgrades this gas to a high-Btu gas (SNG). The process chemistry proceeds in two stages. The first stage involves the deposition of a highly reactive carbon which is derived from the catalytic disproportionation of carbon monoxide in a low-Btu gas ($H_2$, CO, $CO_2$, $H_2O$, $N_2$). The carbon is deposited on a specially formulated ferrous metal catalyst, which is then separated from the hot carbon depleted fuel gas. The highly reactive carbon is then reacted with either hydrogen or steam to produce methane in the second stage of the process. The hot carbon, depleted fuel gas is utilized to produce steam and/or electricity.

Development of the process started in 1976 at the TRW, Inc. laboratories in Redondo Beach, California. Beacon was the name selected for this process concept, which stands for Btu Extraction and Conversion. Sohio joined with TRW in 1978 in a cooperative effort to complete the development effort on this process. In 1980, the Department of Energy entered into a cooperative agreement with TRW to share in the cost of the continued development of the concept. Since the start of this cost shared effort, significant improvements have been made in all phases of the process development. The fluid-bed reactor concept was selected as the preferred mode of operation for the process. Two basically different types of catalysts have been tested and proven suitable for the fluid-bed operation. One is a conventional type of supported catalyst and the second is an unsupported catalyst. These catalysts have been tested under carbon deposition, hydrogenation, and steam gasification conditions at pressures up to 200 psia and in fluid-bed reactors up to 4 inches in diameter. The proof-of-concept stage of this process has been demonstrated. Although the technology is available and ready for transfer to industry, it is not anticipated that such transfer will take place as long as natural gas continues to be available in adequate quantities at reasonable costs.

During the development of the Beacon technology, however, several other interesting concepts, particularly in the area of catalyst development and control of reaction mechanisms were identified. This work has precipitated studies to examine the utilization of Beacon type catalysts for the high temperature selective oxidation of methane at conditions close to equilibrium methane conversion temperatures (1000°C). If successful, this method could lead to reduced production costs in the manufacture of methanol and other chemicals using hydrogen and carbon monoxide as a feedstock.

SURFACE COAL GASIFICATION

Question #6: Please explain what the Advanced Gasification Test Facility is and where it is located. What is the cost of its operation in FY 1984 and FY 1985?

Answer: The Advanced Gasification Concepts Test Facility, which was built at the Morgantown Energy Technology Center (METC), is a unique assembly of moderate-scale equipment devoted to coal conversion research and development and, as far as it is known, is the only facility of its size in the country with such a broad range of temperature and pressure testing capabilities. The facility consists of two separate reactor systems (entrained and fluidized). Each one is housed in an isolated and well ventilated pressure confinement area or cell, and controlled remotely from a nearby control room. Both systems will use coal. Completion of construction of the systems occurred late in calendar year 1982.

The entrained reactor system (3-inch ID; 10 lb/hr; 200-1000 psig; 2000-3000$^{o}$F) is strictly a research oriented system for the investigation of reactions important to coal conversion. The heart of the system is an advanced muffle tube reactor that can achieve temperatures up to 3000$^{o}$F and operates at a pressure up to 1000 psig. With its multiple electric heating zones and numerous supporting flow systems, it provides a carefully controlled environment for the study of reaction phenomena.

The fluidized-bed reactor system (6-inch ID; 150 lb/hr; 200-1000 psig; 1400-1900$^{o}$F) in contrast to the strictly research nature of the entrained system, is a development-oriented system for component testing. Although it can also be used for research applications such as in-bed probing, its main role will be as a flexible gas generator that will produce a characteristic gas stream for other studies. The gasifier itself, with its modular design, multiple feed points, and supporting flow systems can produce a low-to-medium Btu gas of widely varying quality and quantity at pressures up to 1000 psig.

With the entrained reactor system, METC has the capability to study high temperature, high pressure reactions common to entrained gasifiers and to investigate aspects of coal devolatilization. Not only will these studies provide valuable input to the gasification technology data base and modeling activities, but they could also lead to improvements in existing gasifier designs and operation. With the fluidized-bed reactor system, advanced gas cleanup concepts, such as hot desulfurization and alkali removal systems can be tested and integrated with emerging end uses, such as fuel cells. These tests will lead to significant contributions in the use and understanding of coal conversion systems.

With respect to the current status of these systems, shake down tests were started in December 1983 and are presently continuing.

The entrained-bed reactor system will begin Phase I of its test program during the early part of March 1984. The Phase I program will comprise a systematic series of reaction tests on a particular coal and particle size distribution at conditions pertinent to entrained gasifiers. These tests will study: (1) the effects of ambient gas composition on primary devolatization and secondary reactions as a function of temperature, pressure, and residence time; (2) the rates of heterogeneous char reactions; and (3) primary volatiles stabilization by staged injection of steam. The fluidized-bed gasifier demonstration tests will begin in February 1984. The performance of the system will be compared against design and modeling expectations. The applicability of this facility for down stream component testing will also be demonstrated. During the third quarter of FY 1984, a skid mounted hot gas cleanup system (zinc ferrite) which is being developed at METC will be integrated with the fluidized-bed gasifier system and tested.

It is estimated that the cost of operations for the combined entrained and fluidized bed reactor systems will be $1,500,000 for FY 1984 and $1,000,000 for FY 1985.

SURFACE COAL GASIFICATION

Question #7: Please describe the work done at the gasification facility at the Bureau of Mines Center in Minnesota. Is the compilation of this data on fixed bed gasifiers useful to the fossil energy data base?

Answer: The work being carried out at the Bureau of Mines Twin Cities Research Center in Minneapolis, Minnesota, includes obtaining basic research data on the thermochemical response of U.S. coals in a fixed-bed air blown gasifier, development of a complete data base including detailed physical and chemical properties of coal, char, ash, tar, waste water, product gas, and stack emissions, utilization of dirty hot gas generated to develop diagnostic instrumentation and high temperature gas cleanup systems, verification of analytical models developed to predict gasification performance on a wide variety of coals, development of gas sampling techniques which allows reliable tar yield data to be collected for the first time, development of novel gas cleanup concepts and provide performance data for other fuel types (briquettes, pellets, petroleum coke).

The data base being generated at the Twin Cities Research Center under the MIFGA Program is making a strong contribution to the Fossil Energy data base. This data is also being used by industry, universities, and research institutions. The current Inter Agency Agreement with DOI expires on December 11, 1984.

## SURFACE COAL GASIFICATION

Question #8: It was previously proposed to use a coal feeder developed in the DOE program at the Mountain Fuels gasifier in Utah. Has this been done? If so, what have been the results?

Answer: Although preliminary assessments were begun some months ago on the possible installation and test of the DOE/Lockheed kinetic coal feeder at the PDU facility for the High Rate, Entrained-Bed Coal Gasifiers of Mountain Fuels Resources, no action has been taken to date to implement this activity. These preliminary assessments have resulted in some concern about the availability of sufficient time to complete the installation of the feeder, coal transfer system and controls and yet accomplish the required test program. Alternatives are now being considered on ways to accomplish the objectives of the combined project planned for implementation at the Mountain Fuels PDU.

## SURFACE COAL GASIFICATION

Question #9: Please specifically list all gasification facilities that are still included in the DOE program in both FY 1984 and FY 1985. Please explain your reasons for deleting facilities in FY 1985 if such is the case.

Answer: The following is a list of the gasification facilities still included in the DOE program in FY 1984 and FY 1985 with a brief description of the status:

| Facility | Status |
|---|---|
| BIGAS | Solicitation being prepared to seek industrial sponsors to support the utilization of the facility as a generic gasification facility. |
| Advanced Flash Hydropyrolysis (AFHP) Process | Consortium formed to complete the process development effort. |
| Combustion Engineering | Facility disposition efforts have been started. It is expected that they will be completed late FY 1984 or early FY 1985. |
| Advanced Fluidized Bed and Entrained Bed Faclity, METC | Provide basic data on generic coal gasification fluid and entrained bed process. |
| Great Plains Coal Gasification Project | Will come on stream in FY 1984 and will be site for slip stream testing. |

The following facilities were in the FY 1984 DOE program but not in the FY 1985 program:

| Facility | Status |
|---|---|
| Slagging Fixed Bed Gasifier (UNDERC) | Completed slagging environmental studies in support of the GPGA project. No test planned for FY 1985. |

| Facility | Status |
|---|---|
| Pressurized Fixed Bed Gasifier (METC) | Completed environmental evaluation on gas cleanup systems and components evaluation. New advanced fluidized and entrained bed small scale facility ready to take role in this technology. |
| Westinghouse Fluid Bed Gasifier | Completed proof of concept development available funds will carry this program into early FY 1985 and complete existing contract obligations. |
| Mountain Fuel Resources High Rate Entrained-Bed Gasifier | Completed proof of concept testing. |
| Bureau of Mines Twin Cities Fixed Bed Gasifier (MIFGA) | Completed data base evaluation program. |
| General Electric (GE) | Completed dynamic control and modeling effort. |

## SURFACE COAL GASIFICATION

Question #10: Significant funds were provided in FY 1984 for a fluidized bed gasification facility at Waltz Mill, PA. What is the status of funds provided as well as the R&D activities underway? Is there a program to utilize that facility? If so please describe it.

Answer: The funds currently available to the Westinghouse program as a result of Congressional actions in FY 1983 and FY 1984 will carry the program through November 1984. It should be noted that operation through November also assumes the continued availability of funds from Westinghouse and/or the new owner of the Synfuels Division.

The distribution of the funds made available in FY 1984 are as follows:

| | |
|---|---|
| $4,400,000 - | to complete efforts of current contract and support an extension of that contract through August of FY 1984. |
| $2,100,000 - | for new contractual effort or to support termination and new facility disposal activities. |
| $6,500,000 - | Total funding |

The distribution of funds shown below are for the total program and show the level of cofunding available. It should be noted, however, that the $1.8 million figure given for GRI in FY 1983 represents funds actually made available to the program prior to their withdrawal from the project.

Actual/Estimated Obligations
($ in millions)

| | FY 1972-81 | FY 1982 | FY 1983 | FY 1984 | Totals |
|---|---|---|---|---|---|
| DOE | 49.54 | 7.28 | 6.74 | 6.50 | 70.06 |
| GRI | 7.86 | 3.00 | 1.80 | --- | 12.66 |
| Westinghouse | 4.80 | 0.87 | 1.30 | 1.30 | 8.27 |
| Totals | 62.20 | 11.15 | 9.84 | 7.80 | 90.99 |

The current research in progress utilized the fluidized bed gasification facility at Waltz Mill, Pennsylvania, to study the relationships between key operational parameters and the mechanisms controlling ash agglomeration, fluidization phenomena, deposit formation and fines recycle. These studies are being continued on a run-by-run basis that recognizes the current uncertain status of the contractor and any future interest he may have in continuing to work in this area.

This uncertainty is the result of the announced intention by the management of the Westinghouse Corporation to sell their Synfuels Division and to discontinue any further work in the development of synfuels technology. They have also stated however, that they will fulfill their obligations under the current contract they have with the Department of Energy. This contract expires on June 30, 1984.

Although there have been recent announcements indicating that negotiations are underway with a potential buyer of the Division, it is not possible to determine what action Westinghouse or a new participant would take after the expiration date of the contract. DOE's continued access to the site is uncertain.

## SURFACE COAL GASIFICATION

Question #11: Please describe the current work being done on the so-called hydrogasification process with Rockwell. When will results be known from this work?

Answer: Rockwell International's Energy Systems Group in Canoga Park, California, is applying the company's rocket technology experience to a coal gasification method. In this process, pulverized coal is fed at high veolcity by rocket engine injector techniques into a gasifier where it is rapidly mixed and reacted with a hot reaction gas mixture (predominantly hydrogen) to produce methane, the major constituent of natural gas. The Advanced Flash Hydropyrolysis process developed by Rockwell converts coal into a high-quality synthetic natural gas (with high quality benzene byproduct) in less than 10 seconds compared with multi-minute residence requirements of more conventional gasifiers. Under a $1,500,000 contract awarded by the Energy Department's Morgantown (West Virginia) Energy Technology Center, Rockwell and several foreign partners will evaluate the advanced flash hydropyrolysis concept by verifying the reactor chemistry of the process.

Rockwell is now building test hardware and is adapting a one-ton-per-hour process development unit at its Santa Susana, California, field laboratory to simulate the conditions of the process. The actual performance tests, which are scheduled to begin in mid-summer, will be a series of one to two hour test runs. These tests will determine the effect of steam in the gasifier and the type of gaseous reactions taking place, establish reliable material balances, and accurately determine the quantity and makeup of the coal conversion products. Results of this work will be available by May 31, 1985.

If this testing is successful, Rockwell and its partners will be in a position to continue development of advanced flash hydropyrolysis process. Rockwell's partners, who have committed both financial and technical resources to the development of this gasification process, include British Gas Corporation, Gaz de France, SNAM S.p.A. (Italy), and a consortium of seven Japanese companies led by Mitsubishi Corporation. The industrial partners are funding approximately one-third of the project's total $2,300,000 cost.

## SURFACE COAL GASIFICATION

Question #12: Please explain the low cost oxygen separation system concept that is in your budget justification.

Answer: Recent (1980-1983) research advances by the Jet Propulsion Laboratory (JPL) indicate that an efficient, solid state (partially stabilized zirconia) no moving parts, oxygen separation system can be developed.

The oxygen separation capability of zirconia is derived from its ability to function as an electrodialysis membrane. A voltage applied across zirconia results in the conduction of oxygen ions. The ions are formed on the cathode of the zirconia,

$$0 + 4e - 20$$

and recombination occurs at the anode where

$$20 - 0 + 4e$$

Zirconia behaves like a semi-conductor except that instead of conducting electrons, zirconia conducts oxygen ions. The process takes place at temperatures in the range of 350 to 1200°C, and the transferred oxygen is 100 percent pure. This relationship between oxygen partial pressures across a zirconia membrane and the electric potential difference between the two membrane surfaces was discovered over 80 years ago. This principle has been used for years in oxygen partial pressure sensors for oxygen meters and more recently in automobile catalytic converter monitor systems.

Recently (1980), JPL began to investigate the zirconia principle as a means to generate oxygen from the carbon dioxide ($CO_2$) in the

Martian atmosphere. The oxygen would be used as the oxidizer for the return flight from Mars to Earth. The Martian in-situ fuel investigation effort: a) Disclosed that the zirconia cell power loss was much higher than expected, b) Revealed that the large loss was caused by the properties of the electrodes in use at that time, and c) led to the development of a platinum wire mesh grid electrode which achieved low power consumption. JPL advanced the technology further in 1982-83 under a contract with the U.S. Army Harry Diamond Laboratories (HDL). The objective was to determine the feasibility of building a no moving parts, 10cc/minute, pump for a fluidic (no moving parts) tank turret stabilization control system. The total pump-control system would then have no moving parts resulting in very high reliability. The HDL project research established that:

- Platinum was not required as a catalyst to form oxygen ions at the zirconia surface.
- Low power/high cell efficiency could instead be achieved with powder LSM (Lanthanum, Strontium and Manganese) ceramic electrodes. (These two advances would materially reduce cell costs.)
- The LSM ceramic powder electrode could be operated effectively in the 700 to 800°C range. (This advance would allow the use of common metal alloys for the cell structure.)

This earlier work indicates that an efficient, solid state, no moving parts oxygen separation and compression system can be developed. The simplicity of the system and the use of low cost materials and modular design all indicate the potential for a major cost reduction for oxygen separation plants. This is significant since oxygen separation can be 20 to 30 percent of synfuel plant capital costs. In addition, the potential for stand alone maintenance free operation and intrinsic suitability for almost any size construction (especially small sizes) also indicates a potential for many applications where conventional cyrogenic oxygen plants are not practical.

Successful development could result in applications in the synfuels industry, chemical industry, direct combustion systems in utilities, industry and commercial applications and possibly even small personal medical units. Variations of this technology are also being examined for possible $NO_x$ and $SO_x$ gas cleanup and hydrogen separation possibilities.

These studies established that power consumption is a function of a number of variables including zirconia thickness, temperature, current density, cell geometry, air supply blower work and heat recovery efficiency. It is anticipated that a practical combination of parameters will be determined which will result in the zirconia oxygen plant power requirements being less than half the power required for conventional cryogenic oxygen plants.

SURFACE COAL GASIFICATION

Question #13: Please also explain the electroslag casting work being done.

Answer: Electroslag castings are produced through technology similar to that used for producing electroslag remelted ingots. A consumable electrode produced by either rolling or casting is remelted into a water-cooled mold resting on a water-cooled baseplate. Electrical connections are made to the electrode and to the baseplate using a line-frequency transformer as a power supply. Heat is generated in the slag layer by resistance to the flow of electric current or Joule heating. The slag thus superheated causes melting of the electrode tip and droplets of metal shower through the slag layer to form a molten metal pool beneath the slag bath.

The slag also provides a protective environment and metal chemical refinement through the reduction of impurities such as sulfur. Required temperature gradiants are maintained for pressure solidifications of the molten metal with attendant removal, attrition and redistributions of inclusions and gases in the refined metal. Because of this, the ductility characteristics of the electroslag cast metal are markedly improved. The overall result is a directionally-solidified casting free from shrinkage defects, very uniform composition, and usually possessing isotropic mechanical properties generally equivalent to forgings. A continous, thin shell of solidified slag on the mold surface also provides for a smooth, defect-free casting finish.

In brief, the electroslag casting process (ESC) neatly integrates into a compact processing system the diverse tasks of melting, refining and controlling solidifications of the desired alloy composition for the manufacture of exceptionally dense castings. Ultimately, it should be an automatically controlled, very reliable manufacturing process.

The Electroslag Coal Gasification Project was initiated in FY 1982. It is based on an earlier AR&TD materials project with Carnegie Mellon Institute which addressed slag selection and mold economics. The current gasification project is directed toward developing and applying electroslag technology to casting of complex components and reactor vessels. This is a new process which offers the potential for making major reductions in costs when compared to forgings or complete machining of parts from bar stock. If successful, it also will produce parts with superior mechanical properties, reliability and cost savings over sand castings. Cost savings compared to sand castings alone have been estimated to be as high as 50 percent. The process is applicable to present plant component designs as well as sophisticated new, complex equipment designs.

The project consists of two principal efforts:

1. Technology advancement through the development of low cost complex molds, advanced casting techniques and multi alloy applications. (Split molds, fusing ring molds, stationary and movable section molds, combination feed systems for different section thicknesses, metallurgical grain refinements and applications to different alloys.)

2. Technology adoption/transfer through the establishment of mechanical and metallurgical properties for electroslag castings, support of the American Society of Mechanical Engineers (ASME) Code Certification activities and initial application of electroslag casting technology to generic components such as valves, pumps, compressors and vessels.

## SURFACE COAL GASIFICATION

Question #14: With regard to the capital equipment funds requested for fossil energy, $2.5 million is requested for increasing the capacity of the Morgantown ETC data processing center. Please provide some more detailed justification for this need.

Answer: METC has been designated as lead technology center for Coal Gasification, Fluidized-Bed Combustion, Gas Stream Cleanup, Components, Instrumentation and Control, Unconventional Gas Recovery and Heat Engines as a result of its past and present expertise. Automatic Data Processing (ADP) now plays a very important role in this technology development by performing the data base, modeling, and simulation work for these programs.

Prior to 1980, an in-house mini-computer (100 NSU's), in conjunction with resource sharing from an external mainframe, provided approximately 300 NSU's for the computing requirements at METC. In January 1980, a Digital Equipment Corporation VAX-11/780 was installed, and a second VAX was installed in May 1981. Even with this additional equipment which increased METC's NSU's from 300 to 2614, it is estimated that approximately 3750 NSU's will be needed by FY 1985.

The following factors reflect a need for increased ADP capacity at METC: a major change in the research role at METC, from a chemical process hardware-oriented facility to a center for integrated computer-aided fossil energy modeling; and a sudden step-function increase in the number of computer users. System statistics show the result of the changes: response time is already unsatisfactory, job turnaround time has increased, and the systems themselves no longer are running efficiently. This situation allows no flexibility for absorbing incoming users. Postponement of the proposed acquisition would not only impair ongoing and planned work, in many cases it would also prevent this work.

## SURFACE COAL GASIFICATION

Question #15: With regard to the waste water treatment facility in Morgantown, has the facility consistently been on the same schedule that it is now, or was the project delayed? If so, please describe the reason for such delays.

Answer: The waste water treatment facility project in Morgantown has been delayed from the original schedule submitted in FY 1983. The project has been delayed for the following reasons:

- The A-E origination work was slipped from second quarter, FY 1983 to third quarter, FY 1983, due to scope and design changes and procurement slippages.
- The start date for physical construction was slipped from first quarter, FY 1984 to third quarter, FY 1984, due to design schedule slippage in the first quarter and inclement weather in the area for the second quarter.
- The date construction ends was slipped from first quarter, FY 1985 to fourth quarter, FY 1985, due to beginning the physical construction late and developing a better defined construction schedule estimate.

## SURFACE COAL GASIFICATION

Question #16: Please provide some detail for the general plant projects activity for fiscal years 1981 thru 1984 with regard to the type of project and the energy technology center involved. Please also provide some detail as to the types of proposed projects for FY 1985.

Answer: PETC was allocated $1,100,000 in FY 1981, $730,000 in FY 1982, $370,000 in FY 1983, and $875,000 in FY 1984 for funding of General Plant Projects (GPP). These funds were used for projects such as soil stabilization in the area of an H-gas storage tank ($252,000); OSHA corrections to PETC cranes and equipment ($19,000); construction of a hazardous materials storage facility ($150,000); and conversion of laboratory space to office space in Building 167 ($200,000). The FY 1985 request is $800,000.

METC was allocated $634,000 in FY 1981, $1,008,000 in FY 1982; $58,000 in FY 1983, and $875,000 in FY 1984 for GPP. These funds were used for such projects as construction of a 75 KVA transformer station ($110,000); computer room cooling ($448,000); reroofing of Buildings 3, 4, 5, 7, and 8 ($132,000); installation of a air cleanup and monitoring system in Building B-5 ($35,000); and replacement of electrical distribution panels in Pilot Plant, Building B-4 ($200,000). The FY 1985 request is $1,200,000.

BPO was allocated $383,000 in FY 1981, $400,000 in FY 1982, $336,000 in FY 1983, and $250,000 in FY 1984. These funds were used for such projects as improving the ventilation system in Building 6 ($118,000); conversion of the library in Building 3 to office space ($124,000); installation of emergency ventilation and emergency alarm system in Building 3 ($92,000); and installation of automatic sprinklers in Building 1 ($170,000). The FY 1985 request of $500,000.

While final funding allocations for FY 1985 have not as yet been made, it is anticipated that priority will continue to be given to fire, safety, OSHA, and environmental projects. The following type projects are under consideration for funding in FY 1985.

PETC

- o Installation of an alarm notification system extension in Buildings 64, 141, and 922.
- o Improvements to health care facility in Building 58.
- o Modification of Building 922 to provide central computer facility.

METC

- o Cover, pave, and dike drum storage area in the chemical storage area.
- o Install coal dust collection system in Building B-14.
- o Construct main frame computer building.

BPO

- o Replace HVAC system in Building 3.

The attached Summary of General Plant Projects exhibit summarizes the Fossil Energy funding for GPP for FY 1981 through FY 1985.

## SUMMARY OF GENERAL PLANT PROJECTS

($ IN THOUSANDS)

| Contractor | ACTUAL B/A FY 1981 | ACTUAL B/A FY 1982 | ACTUAL B/A FY 1983 | EST. B/A FY 1984 | REQUESTED B/A FY 1985 |
|---|---|---|---|---|---|
| PETC | $1,100 | $ 730 | $ 370 | $ 875 | $ 800 |
| Laramie Project Off. | 443 | 370 | 86 | 0 | 0 |
| METC | 634 | 1,008 | 58 | 875 | 1,200 |
| Grand Forks Proj. Off. | 440 | 372 | 150 | 0 | 0 |
| BPO | 383 | 400 | 336 | 250 | 500 |
| Total GPP | $3,000 | $2,880 | $1,000 | $2,000 | $2,500 |

## SURFACE COAL GASIFICATION

Question #17: Please explain why the work on water removal and processing of low rank coals was stopped.

Answer: The studies on water removal and processing of low rank coals are not being stopped. This work will be continued as part of the studies being preformed by the University of North Dakota Research Center under the direction of the Grand Forks Project Office.

In FY85 the following work has been proposed by GFPO as part of their institutional plan program. We are currently considering this work in our FY85 Program Planning Cycle.

| Proposed Level of Funding | Description of Activity |
|---|---|
| Coal Preparation - $305,000 | Complete construction of a low rank coal hot water drying PDU and determine the process conditions required to produce a high solids concentration slurry of increased heating value for applications as feed to an entrained bed gasifier and/or direct coal fired combustor. In addition determine the inter-relationships between the drying process conditions, the resulting composition of the slurry, its rhelogy and stability characteristics. The data will help establish LRC as potential feedstocks for advanced gasifiers. |
| Surface Coal Gasification - $210,000 | |

ADVANCED PROCESS TECHNOLOGY

Question #1: Please explain how your work in the Arctic ties into what is being done by the U.S. Geological Survey and the Bureau of Land Management with regard to Arctic oil and gas development. What kind of mechanism is set up to assure that you are doing work that is not being duplicated by others, such as the Survey? You speak of consolidated Arctic and offshore oil and gas data. Where is this data consolidated? Is this data base separate from that of the Geological Survey and the Bureau of Land Management?

Answer: Although much research has been done by the Government and private industry, the quality and quantity of scientific data for Arctic oil and gas engineering technology vary widely. After a recent reorganization, Department of Interior Arctic oil and gas responsibilities are now shared by the Minerals Management Service of the Department of Interior/U.S. Geological Survey. The USGS is engaged in a number of activities related to petroleum exploration and development in the Alaskan Arctic. These activities include studies on seismicity, landslides, active faulting, sediment dynamics, ice-sediment interactions, shallow and deep gas, and geotechnical engineering. Results of these USGS studies are provided to petroleum operators as design constraints or hazards for offshore operating structures.

DOE's Arctic activities primarily focus on providing industry with oil and gas-related research information by compiling relevant data from research conducted by other government agencies and private industry in these frontier regimes. DOE will also conduct selective, limited research to fill key data gaps. In this way, a relatively small Department of Energy research investment may provide an important key to unlock the resource potential of 50 billion barrels of oil and 750 trillion cubic feet of gas that are estimated to be contained in the Arctic/Offshore environment.

To ensure effective coordination, the Arctic and Offshore Research (AOR) Program conducts seminars and workshops to acquaint participants (government, industry and academia) with the current DOE/Fossil Energy AOR program and to obtain feedback from the attendees. Meetings, briefings and personnel contacts keep all apprised of the DOE/Fossil Energy effort on a short turn around.

An Arctic oil and gas-related technology data base is necessary in order to ensure technology transfer of all available Arctic research to Arctic private sector operators. Considerable data is available for these areas; however, extensive data resides in the files/data banks of various Governmental and industrial bodies, and is not centrally located, nor is it accessible in a correlated and readily usable manner. A data base system is being designed to identify, coordinate, and correlate all available Arctic/offshore environmental and engineering research data. Furthermore, this data, as it becomes available, can be used to develop Arctic engineering/environmental models. This computerized oil and gas data base will be located at the Morgantown (West Virginia) Energy Technology Center and will be available and accessible to all government, industry and academia users. A prototype of the MIS for Arctic research should be completed by September 1984. The comprehensive scientific and engineering data base is a long term project and may take several year to complete.

This data base is separate from that of the Geological Survey and the Bureau of Land Management. The DOE/Fossil Energy Arctic and Offshore Research program goal is to reduce the technical and economic uncertainties to the development and production of the Alaskan Arctic oil and gas resources. A consolidated Arctic and offshore oil and gas data base has been the common request of interested industry, government and academia.

## ADVANCED PROCESS TECHNOLOGY

Question #2: What are the major oil companies doing in Arctic and offshore research?

Answer: Industry's Alaskan Arctic Oil and Gas R&D efforts are primarily being carried out by the Alaska Oil and Gas Association (AOGA) and individually by a relative few major oil companies. Many of the second-tier major and independent oil companies are not actively involved in Arctic R&D but are instead relying on AOGA and the majors to advance the state-of-the-art knowledge of oil and gas exploration and development.

AOGA, a trade association with 37-member companies, accounts for the majority of exploration, production, and transportation research activities in the Arctic. A special research group, the Lease-Sale Planning and Research Committee (LPRC), was established by AOGA in 1978 to conduct studies of important issues. Members of LPRC (at present, 14 petroleum companies) selectively participate in joint industry research projects dealing with aspects of Arctic exploration, production, and/or transportation. Member companies have participated in approximately 210 projects to date with a total investment of over $50 million. Over 80 projects have dealt with sea ice characterization, since sea ice is a major concern due to its pervasive influence on all aspects of Arctic operations. Nearly 30 projects have dealt with platform and artificial island design and construction. The remaining projects have been concerned with oceanography (wind and waves), geotechnical evaluations (permafrost), transportation (terminals, ice breakers), pipelines (burial techniques, gouging), seismicity, and environmental impact (cleanup, endangered species). AOGA's 1983 R&D budget was approximately $15 million.

Industry is also involved in Arctic research on an individual company basis to keep their respective competitive edge in the lease-sale bidding process. This research is, therefore, proprietary, and it is very difficult to determine the status of energy-related Arctic research. However, to obtain some knowledge of industry research, DOE solicited information from 10 leading Arctic operators on research issues and the perceived data needs as viewed by each company. In addition, recommendations for a Federal role were solicited.

The total industry Arctic research expenditure for 1983 was estimated to be $15- to $20-million. Industry focused their research on sea ice and its effect on the working environment. Hence, studies in ice structure interaction, multi-year ice characteristics, and ice movements are being advanced. Other research categories having lower levels of industry activity are in the biological sciences, materials testing, and oceanography.

There are several topics that industry indicated as requiring more in-depth research and Federal involvement. The two issues most frequently cited by the companies deal with offshore structure design for deep Beaufort Sea exploration and the development of an Arctic research data base. The first, because of multi-year ice and the Beaufort Gyre, causes an overextension of current technology and may force industry to go below the Arctic ice canopy to develop the Arctic oil and gas resources. In the second, the need for a consolidated and comprehensive data base was viewed as vital to the industry's Arctic R&D effort.

## ADVANCED PROCESS TECHNOLOGY

Question #3: Please provide some project descriptions for your advanced exploratory research, explaining what types of research are involved in this type of program. Please also provide a breakdown of how much of this research is done in universities, how much is done in industry, and how much, if any, is done at the Bartlesville facility.

Answer: The Advanced Exploratory Research program has been organized into three distinct research areas: Advanced Extraction Technology, Fundamental Petroleum Chemistry, and Advanced Utilization Technology.

Project descriptions, locations and funding are:

- Advanced Extraction Technology
    - Microbial enhanced oil recovery research (Four (4) universities, $650,000)
    - MEOR Environmental Research (NIPER, $390,000)
    - Advanced extraction instrumentation development (LLNL, SNL, $300,000)
    - Subsidence and aquifer restoration research (SNL, WRI, $250,000)
- Fundamental Petroleum Chemistry
    - Thermodynamic characterization of organic nitrogen compounds that occur in shale oil and heavy oil (NIPER, $400,000)
    - Stability and processing research for crudes, intermediate process streams and finished fuels (NIPER, $400,000)

- Chemical characterization of heavy ends of light and heavy petroleum, and of liquids derived from other fossil sources (NIPER, $400,000)
- Fuel trends research and analyses (NIPER, $10,000)
- Supercritical fluid extraction processes research on shale oil recovery (WRI, $350,000)
- Toxic heavy metals removal research (LBL, $100,000)
- Cooperative stability research (with DOD) on alternative fuels storage and transportation stability (NRL, $158,000)

o Advanced Utilization Technology

- Diesel fuel quality criteria engine testing (NIPER, $300,000)
- Research on the direct utilization of aromatic feedstocks (NIPER, $300,000)
- Diesel exhaust characterization (NIPER, $300,000)

Acronym key:

LLNL - Lawrence Livermore National Laboratory
SNL - Sandia National Laboratory
WRI - Western Research Institute
NIPER - National Institute for Petroleum and Energy Research managed by the IIT Research Institute
LBL - Lawrence Berkeley Laboratory
NRL - Naval Research Laboratory

ADVANCED PROCESS TECHNOLOGY

Question #4: Please explain what types of advanced extraction instrumentation and in-situ monitoring instrumentation are being developed.

Answer: DOE has funded Lawrence Livermore National Laboratory (LLNL) to investigate the use of High Frequency Electromagnetic (HFEM) signals to find zones of differing impedance in reservoirs. LLNL has also begun work using seismic signals which can locate zones of high signal attenuation and/or velocity change. A combination of electromagnetic and seismic signals may be necessary to adequately determine steam/combustion zones during in situ extraction operation. LLNL is now conducting seismic tests at a Getty Kern River field site. The development of sending and receiving devices to withstand high temperatures has become a primary need and is being addressed at UHL. Field testing at the Getty site will continue through FY 1985.

DOE has also funded Sandia National Laboratory (SNL) to develop the Controlled Source Audio Frequency Magneto Telluric (CSAMT) technique for the past few years. It is basically an electromagnetic sending-receiving technique that uses low frequencies, roughly in the range of 50-100 Hz. An important difference is that signals are sent and received on the ground surface, rather than from specially drilled wells as with the LLNL HFEM technique. This limits CSAMT application to relatively shallow fields without water zones above the reservoir. Even with this restriction, the technique is very attractive because of the potential ease of operation. SNL will continue with in-house lab tests and data analysis through FY 1985.

## ENHANCED OIL RECOVERY

Question #1: Your justifications indicate an advanced enhanced oil recovery potential of from 1.4 to 2.7 million barrels a day between 1990 and the year 2000. Please provide some information as to how those figures were arrived at and what types of technology would contribute to those totals, and to what extent?

Answer: Enhanced Oil Recovery (EOR) is the generic phrase defining a wide variety of techniques for producing oil that will be abandoned as conventional recovery processes are exhausted. This oil, termed residual oil, amounts to two-thirds (300 billion barrels) of all oil discovered to date in the United States. It is unproducible by conventional techniques because it is held by interfacial tension in zones of the reservoir swept by conventional water or steam injection, or lies in zones that cannot be reached by conventional processes. EOR techniques, highly specific to particular reservoir and crude oil properties, are designed to overcome the constraints that trap residual oil in the reservoir.

A number of detailed studies of the potential for EOR to produce residual oil have been conducted. These are summarized in the table below:

|  | Estimated Ultimate Recovery (Bill B.) |
|---|---|
| National Petroleum Council, 1976 | 9 - 32 |
| Lewin and Associates, 1978 | 17 - 37 |
| Office of Technology Assessment, 1978 | 25 - 41 |

All three studies relied on highly detailed, reservoir-specific analyses of the anticipated performance of the respective EOR processes. Their range suggests the uncertainty in such projections. The additional uncertainty of the timing of production reveals an even wider range. The time-rate estimates used in the justification relied on the Lewin study because it was the more conservative estimate that explicitly considered technological improvement. (OTA was considerably higher and the NPC study did not vary technology). As noted, these estimates were based on detailed reservoir data and explicit, engineering definitions of process performance. The analyses of advanced EOR technology assumed a level of EOR process performance that could be defined in explicit engineering terms which could be inferred as feasible from theoretical and experimental considerations. Note, however, that these levels of performance exceed that of EOR processes actually in field use. These estimates are incremental to production from EOR techniques that are currently in use, or are being developed in industry laboratories. Thus, these are the best available estimates of the impact of technological advances.

Currently, however, the National Petroleum Council, at the request of the Secretary of the Department of Energy (DOE), is performing a detailed, substantive reanalysis of the potential of EOR. Their conclusions are expected in late spring of 1984. These will provide a more current assessment. The NPC study is being supported by the reservoir data, process performance models, and systems maintained by the Federal EOR Research Program. The NPC is validating these and conducting its analyses using the program's systems. This close collaboration will result in the program having the most current and valid systems for estimating future EOR production and for performing sensitivity studies of critical geological and technical uncertainties in estimating the potential of EOR. Industry anticipates that DOE will maintain this information in useable form so that the impact of EOR on future domestic production can be continuously assessed.

The technology advances that are expected to yield the projected additional production are now too poorly understood to permit reliable prediction of performance. Relatively predictable EOR processes (e.g., conventional steam drive in California heavy oil reservoirs; carbon dioxide floods in the Permian Basin, carbonate reservoirs) are not included in this estimate. The Federal EOR program is focused on increasing the understanding and predictability of these processes that may apply in less forgiving reservoir environments (e.g., deeper, thinner, heavy oil reservoirs; light oil sandstone reservoirs).

## ENHANCED OIL RECOVERY

Question #2: Please explain the role of DOE with regard to enhanced oil technology versus that of industry. For example, in $CO_2$ flooding you are proposing to do some increased work. How does this tie into industry use of $CO_2$ flooding which is apparently increasing? What are you doing that is not being done by industry, and how will this assist them?

Answer: The federal EOR research program expects industry to develop and apply EOR processes as available understanding and economic conditions warrant. It conducts neither developmental engineering nor process refinement. Rather, it investigates the fundamental reservoir-fluid properties that trap residual oil and potential means of displacing and mobilizing this oil. The federal EOR research objectives are as follows:

- Perform the basic, fundamental research that contribute to the knowledge base that will make advanced EOR processes more predictable;
- Investigate the basic feasibility of novel approaches to solving problems that limit the effectiveness on applicability of EOR; and
- Uniquely, define overall potential and critical scientific uncertainties through public, indepth analyses of the performance of specific field tests and nation-wide assessments of the EOR state-of-the-art and potential contribution to domestic production.

The federal EOR research program conducts extensive analyses to assure that its focus is on the highest priority uncertainties. In this way, its contributions have maximum utility to industry and to the public, agencies which require this information. Three program "products" are particularly relevant in this regard.

- Through detailed, engineering analysis of the differences between predicted and actual performance of specific field tests, as interpreted through statistical appraisals of all similar reservoir-process combinations, the program can provide improved detailed understanding of the predictability of process performance to private operations, thereby accelerating application of EOR processes that are adequately predictable;
- Through in-depth sensitivity analyses of the principal technical unknowns of the residual oil resource and of highly specific research results, the program can define the critical uncertainties to private and public EOR researchers, who then may focus their efforts and accelerate the generation of highly relevant, but fundamental EOR scientific research; and
- By overall assessments of the productive potential of current and future EOR technologies, the program can provide to public and private decision- makers vital, technically sound projections of the EOR contributions to future domestic crude oil production; because EOR is likely to contribute the largest such increment (relative to new discoveries, extended productive of marginal wells, or synthetic fuels), this information could be extremely important to national energy policy considerations.

The questions specifically references carbon dioxide flooding. Ninety percent of production from $CO_2$ flooding today comes from six carbonate reservoirs in West Texas (e.g., Sacroc, Wasson). These reservoirs are uniquely suited to $CO_2$ flooding, being relatively thick, high pressured, and high in residual oil saturation. The three $CO_2$ pipelines that are under construction, or currently planned, will provide the gas to expand EOR production in these and highly similar, co-located reservoirs. Even in these highly favorable settings, industry acknowledges that viscous fingering and gravity override — together contributing to by-passing a significant amount of the resource -- will be major limitations to effectively producing all of the residual oil. Sufficient oil will be recovered to be economically attractive, but much will be left behind. Industry's research to overcome these problems has focused on near-term improvements because the schedule of these projects is largely driven by the $CO_2$ pipeline availability. The federal EOR research program addresses the more fundamental question of controlling the mobility and conformance of $CO_2$ flooding. This research may result in information which would permit various operations to produce more oil by sweeping portions of the reservoir that otherwise would have been by-passed. However, the federal program's research also addressed $CO_2$ flooding in sandstone reservoirs, dipping (inclined) reservoirs, and other settings where $CO_2$ flooding has yet to be shown to be effective.

A similar example can be cited with heavy oil. Thermal EOR production of heavy oils currently account for 79 percent of all U.S. EOR production. Of this, however, the highly favorable reservoirs of Kern County, California, account for 77 percent -- i.e., 61 percent of all U.S. enhanced recovery comes from one county in California. Once again, the highly favorable reservoir conditions (thick, high permeability, good oil saturation, shallow) permit economic production.

The reservoirs of the Permian Basin and Kern County, however, are the atypical example. Because they are profitable, significant EOR projects have been initiated. The vast majority of the U.S. residual oil recovery, however, is not favored. Federal EOR research is focused on these less favorable reservoirs where the bulk of the resource ends.

## ENHANCED OIL RECOVERY

Question #3: You state that you will evaluate and develop new concepts for in-situ recovery of bitumen from tar sands. What kinds of new concepts are you talking about?

Answer: Unlike conventional oil and heavy oil resources, the bitumen in tar sand formations has extremely high viscosity and cannot be produced without heating (viscosity declines exponentially with temperature). Heating appears to be the only forseeable and practical approach to the extraction of bitumen of tar sands.

Our effort will be directed toward the fundamental understanding of what takes place in the reservoir upon heat injection, be it in the form of steam (continuous of cyclic) or in situ combustion (dry, wet forward or reverse, or any combination thereof). The research will be limited to laboratory, bench scale experimentation on physical models now under construction. The work will be amplified by the existing cooperation on tar sands R&D with Canada to save human and material resources and to draw upon the only extensive research effort on their tar sand resources, referred to as "oil sands".

More specifically, laboratory experimentation will entail tests with the combination of steam flooding and fireflooding under various modes of operation. Experiments will also be done with reverse in situ combustion to preheat the reservoir and to create communication, followed by forward in situ combustion to sweep the already heated bitumen. All experiments will be conducted on small scale test apparatus. No field tests are now being contemplated.

In FY 1986/87 we may experiment with oxygen rather than air for the in situ combustion in tar sands.

Certain other futuristic approaches include volumetric heating by radio frequency waves and the use of microbial methods. The latter is thought promising by some researchers, but it is only a concept at this stage. Such investigations may be carried out past FY 1985, if the laboratory investigations into the fundamental thermal release mechanisms warrant work this area.

In summary, novel concepts will evolve from an understanding of the key parameters and mechanisms for displacing and mobilizing the tar sands in in-situ processing. Also, new concepts can be evaluated only through an understanding of the thermal processes.

## ENHANCED OIL RECOVERY

Question #4: Please explain what fundamental work you are doing in micellar-polymer research in light oils.

Answer: Fundamental research of the surfactant (micellar)-polymer process for light oils is being performed in those areas which continue to constrain its performance in an efficient and predictable manner.

NIPER and seven university basic process research programs aimed at increasing the understanding of the chemical flooding process which includes rock-fluid interactions, physico-chemical properties or surfactants and polymers, displacement mechanisms, reservoir conformance, and process predictability. More specifically, areas of research include the following:

- o Surfactant/Polymer Displacement Mechanisms - identify the role of various crude oil fractions on phase behavior and interfacial tension, and develop a 3-D compositional process model.
- o Surfactant/Polymer Retention - study and quantitatively describe mechanisms of adsorption to develop methods to reduce adsorption.
- o Surfactant Fundamental Research - develop a quantitative, basic understanding of surfactant behavior in aqueous solution so that rules or criteria for formulating an optional surfactant slug can be established.
- o Thermodynamic Characterization of Surfactant Fluids - develop theories of micellization and solubilization, mass-action numerical models, determine thermodynamic properties, and improve diagnostic techniques.

- Quantitative Methods in Surfactant Behavior Research - develop equations and correlations concerning interfacial tension, phase behavior and thermodynamics.
- Reservoir Heterogeneity Research - emphasize the role of variations in reservoir properties, both at the micro and macro levels, that affect sweep and displacement efficiencies.
- Improved Chemicals for Conformance/Mobility Control - synthesis, characterization and rheology of model polymers for mobility control and area sweep, characterization and kinetics of in-situ gelling systems for improved vertical sweep.
- Synthesis and Molecular Design of Surfactants/Amphiphiles for Flooding Systems - improve stability of hostile, variable reservoir environments, e.g., temperature and salinity, maintaining low interfacial tension and mobility.

These activities are part of an overall process research plan which utilized the input and guidance of industrial and academic peer reviews.

## ENHANCED OIL RECOVERY

Question #5: Please explain your experimentation on controlling steam mobility in heavy oil reservoirs. What kinds of projects are involved? When do you think this can be tested on a larger scale?

Answer: The DOE program for using chemical additives to improve steamflood oil recovery performance began in 1977. Two contracts were let to universities, primarily addressing steam additives R&D. The first contract was awarded to the Stanford University to sponsor its Petroleum Research Institute (SUPRI). SUPRI has five separate research tasks, but the primary focus is research on foaming chemicals to reduce steam mobility in the reservoir. SUPRI screened many surfactants for foaming ability, high temperature stability and absorption characteristics. Several types of modeling experiments are carried out to understand flow mechanics.

The second university contract was to Southern California, to research the potential use of surfactants for moving oil by interfacial tension reduction in conjunction with steamflooding. This work is distinctly different from SUPRI's and has not yet led to field tests.

Based on encouraging results from early work at SUPRI on foams, we two field test contracts were awarded to CLD Corp. and Corco on 09/30/79. A third field test was conducted later by SUPRI. The CLD contract actually consisted of five short duration mini tests. A foaming chemical solution was injected with air or nitrogen intermittently over a period of 2-6 months, depending on the particular test. Tests 1 and 5 were conducted in the same site and were highly successful. Production increased about four-fold on average, over a period of six months on both tests. The other three tests showed little or no oil production increase, but effects of the chemical in the reservoir were noted.

The Corco test injected a different foaming chemical intermittently over a period of two years into several wells. A marginal oil production increase was noted and the test could be called a limited success. No dramatic oil increase was observed which could be directly attributed to chemical injection, as were the case with two of the CLD mini tests.

The third field test was conducted by SUPRI and was a technical success. A third different foaming chemical was injected into a steam injection well intermittently with nitrogen during three separate test periods. In each test period, additional oil production was observed ranging from 30 to 100 percent increases. Other effects on the reservoir were also noted.

In addition to these three DOE funded field tests, a major oil company has reported on their own successful test of a steam additive. The four tests have created much interest in the use of foaming chemical. The major oil company that conducted their own test believes that steam additive chemicals will become standard for use in steamfloods. A second major oil company is beginning a field pilot and believes that either steam additives or in fill drilling will become standard in recoverying additional steamflood oil. A third major oil company believes that steam additives may only be useful in poor performance steamfloods. A fourth company is testing several different types of chemicals for use with steam. Thus, there is no consensus on the use of additives yet. Furthermore, the field tests have probably raised more questions than have been answered about these chemicals. The two most successful tests by CLD may not be the result of steam mobility reduction, or "foam blocking". The chemical may have acted as a interfacial tension reduction agent or a weak emulsifier.

The current DOE program centers on basic research to learn more about the mechanisms of how these chemicals work, or do not work, as the case may be. It appears that industry is enthusiastic enough about steam additives to conduct further field tests. Steamflooding is now a mature technology, producing over 400,000 barrels per day in California.

## ENHANCED OIL RECOVERY

Question #6: Please describe the need for increasing your work in the light oil area. How much of this increase is in experimental testing versus the development of models and analysis of existing data?

Answer: The U.S. is blessed with an enormous resource of light oils. Of the total 300 billion barrels of residual oil, nearly 80 percent has gravity higher than 20°API. The majority of this is trapped by interfacial tension or is unreachable by conventional flooding techniques. Aside from the production from a relatively small number of highly favorable Permian Basin reservoirs, light oils account for less than 2 percent of EOR production. The EOR techniques appropriate for producing light oils -- principally chemical and gas flooding, with possible contributions from novel microbial and steam techniques — have yet to be demonstrated as predictable and effective.

The low level of light oil EOR production stands in stark contrast to the incentives that have been made available to stimulate such production. Around twenty light oil projects were cost-shared by the Federal Government and industry; more than 300 light oil projects were stimulated under the Tertiary Incentives Program; still more through special provisions of the Windfall Profit Tax; and U.S. domestic oil price has increased nearly two and one-half times (in real terms) in the last eight years. All of this activity has failed to yield any significant production because the individual projects have been predominately small pilot tests. The results of these tests have been so unpredictable and discouraging that the anticipated expansion from pilot to full-field development has not taken place.

The reasons for this unexpectedly poor and generally discouraging performance is that the basic process mechanisms are too poorly understood to permit reasonable prediction. These same processes have been demonstrated to perform in laboratory experiments and theoretic mathematical simulations have indicated that they should work well in the field. However, neither the laboratory or theoretical work has been successfully translated to field applications. In brief, most light oil field projects have failed to perform as predicted and no one knows for certain just why. Given this lack of understanding, enhanced light oil production has proven largely insensitive to economic incentives.

The Federal EOR research program is explicitly focused on improving this inadequate understanding of the EOR processes as applied in the reservoir. As this question implies, both analysis and experimentation are required. In fact, they are intimately related. The typical sequence is to analyze specific field tests (usually cost-shared or incentive tests) in great detail to generate one or more hypotheses to explain the observed performance. Such detailed analyses may entail simulator history-matching collection of additional data from operations or from the reservoir, etc. The interpretation of a particular test provides only one data point.

To determine whether the hypothetical interpretation is idiosyncratic to the particular pilot site or has a degree of generality to a class of reservoirs or particular process designs, the hypotheses are tested statistically against a number of comparable projects whose data are maintained in the programs's EOR project file. This may lead to further refinement of the hypotheses based on the individual test. Once the hypotheses are refined, they are examined for their impact on recoverability of the overall residual oil resource base. Those that have significant impact are defined as "critical" uncertainties as hypotheses. Such critical hypotheses can only be tested through scientific experimentation. The Federal EOR research program uses a combination of chemical, physical, geophysical and geoscience approaches to perform the vital scientific experimentation -- all focused on specific critical hypotheses.

This work generally results in improved understanding of the process mechanisms. Such improvements are "captured" in the detailed understanding of the processes and are quantified in detailed process simulators. These, in turn, are improved through the interaction of scientific research and in-depth analysis. Through this process, the ability to predict the performance of light oil enhanced recovery processes in actual reservoir settings will improve. With improved predictability, economic forces will stimulate enhanced light oil production as the market requires it.

Although both analysis and experimentation are intimately interrelated in the program's logic, they are not equally costly. While analysis is vital to defining the critical hypotheses which focus the experimental research, it accounts for less than 20 percent of the overall EOR research program budgets.

## ENHANCED OIL RECOVERY

Question #7: Please describe your existing data bank,, how it gets updated, how the data gets to industry, and what input industry has to the development of the data base.

Answer: The Tertiary Oil Recovery Information System (TORIS) resident at the Bartlesville Project Office (BPO) is an integrated system of data, software, and continuing analysis that pulls together the currently available understanding of the EOR resource and technology. This permits analyses ranging from narrowly focused studies designed to identify and explain differences between expected and observed results from specific EOR field tests to broad based assessments of EOR state-of-the-art and potential necessary to arrive at rational trade offs among alternative R&D objectives within the Federal EOR research program.

The TORIS is composed of several major discrete data bases and analytical elements:

- EOR Project Data Base: detailed reservoir, design, and performance data on more than 400 actual field EOR projects;
- EOR Reservoir Data Base: detailed engineering and geological data on 3700 reservoirs, accounting for 73% of known U.S. oil;
- Crude Oil Analysis Data Base: data on analyses made on more than 9,000 crude oils (8,500 U.S.). Some 70 different data elements are contained for each sample.
- Abandoned Oil Fields File: data on 4,300 U.S. fields abandoned through 1982;

- EOR Process Models: engineering models that predict incremental EOR as a function of individual reservoir properties and various specific process designs for six major EOR processes;
- EOR Costing Models: engineering algorithms that estimate all investment and operating costs of an EOR project as a function of reservoir properties and EOR process designs;
- EOR Investment and Phasing Models: models that evaluate economic feasibility of individual EOR projects; schedule economic projects in light of relative investment efficiency and a variety of environmental, logistical, and financial constraints; and project EOR production overall.
- Integrating Software: programs that relate the data bases and models for comprehensive, integrated analyses.
- Access to results of the latest laboratory research in all areas relating to EOR, including geoscience.

Collectively, these components permit TORIS to capture and synthesize the present knowledge of the EOR resource, current and future technologies, and technical and economic constraints.

The information currently contained in TORIS is a direct result of more than $4 billion in direct Federal outlays, tax incentives and price relief related to Enhanced Oil Recovery (EOR). Specific investments in the construction of the TORIS began in 1975 and the public and private sector investment exceeds several million dollars.

Numerous private organizations are actively cooperating in the construction and validation of TORIS. The National Petroleum

Council (NPC) used prototype screening models and early versions of the reservoir and project data bases developed at BETC as the analytical nucleus of their current update of the 1976 study of U.S. EOR potential. The NPC has spent an estimated $6.7 million on this study and has expressed an interest in DOE's maintenance of the data bases and models it has validated in an up-to-date form so that public organizations and industry at large can have the benefit of the most current estimates from the base that the NPC has established.

Updates to the reservoir data base will be achieved through intensive review of the reservoir data in the current NPC file and incorporation of other large volumes of data resident at BPO and not incorporated into the NPC study because of time constraints. Further, two-thirds of the operators who took advantage of the EOR Incentive Program voluntarily continue to report their projects on an annual basis despite the lifting of reporting requirements. These reports are incorporated into the project data base. Other sources of information are the Society of Petroleum Engineers (SPE) who maintain an active series of project-specific engineering reports, a monograph series on EOR, and a bi-annual symposium on EOR conducted jointly with DOE. Other obvious sources are trade journals, (Oil & Gas Journal, etc.), and technical literature (SPE, USGS). State agencies' reports are routinely accessed for reservoir data, injective project data, tax and royalty rates, and environmental and other constraints. Federal information sources provide energy policy guidance, projected crude oil prices, domestic conventional reserves and production forecasts and cost and investment analyses.

There are two chief user groups of the product of TORIS. They are the public sector, consisting of federal, state, academic, and individual users and the private sector - energy companies and consultants. The bulk of the private sector users are reached through regularly published reports such as the Enhanced Oil Recovery. Quarterly Progress Reviews which summarize research relating to screening models and data base development. A series of reports describing abandoned oil fields in all producing states was released in 1982-83. They are now in their second and third printing. The Bartlesville Project Office maintains the crude oil analysis data base in telephone accessible form. A recent publication (DOE/BETC/SP-83/27, January 1984) was released which describes and lists the contents of the EOR project data base. Reports or research related to three EOR process screening models prepared under contract for DOE (and used by NPC in their present study) are in the publication process. Also, the DOE developed reservoir and process data bases and screening models that were provided in their entirety to the NPC and are key to the NPC's EOR study. The joint SPE/DOE Enhanced Oil Recovery Symposium, held by-annually in Tulsa, Oklahoma, is another important vehicle for TORIS related material to be transferred to industry.

The value of the TORIS to the public sector user must also be addressed. While this user- group has access to the resources described above, an even more important function of the system is to address specific needs which are best served by direct response to that user. The following specific examples are cited of recent interest in applying TORIS to their problems:

- o Within the Department of Energy:
  - FE line and staff officials, in considering strategy development;
  - EIA, in making its annual forecasts;
  - Emergency preparedness officials, in considering overall emergency response strategies;
  - Policy and Evaluation has expressed the desire for more accurate fossil energy production projections, a key component of which would be EOR as analyzed by TORIS.

- o Other public agencies:
  - Department of Interior, in managing Federal lands, especially offshore;
  - GAO and OTA, in assessing the role of EOR in Federal energy policy and future supplies;
  - Interstate Oil Compact Commission, in preparing its EOR research plans and in analyzing several state-level economic issues;
  - Several states, in evaluating EOR's effects on their economic and tax bases;
  - Venezuela, under bi-lateral agreement, in developing additional EOR process models which will be provided to DOE in exchange for the TORIS process models.

OPPORTUNITIES FOR INDUSTRY INPUT This part of the question relates in large part to an earlier one on how the system gets updated. A major component of the TORIS is the reservoir data base and screening models. The NPC, from the outset of their 1983-84 EOR study, determined to use these elements of TORIS as their primary analytical tools. Inherent in their use was the availability of Key BPO staff to operate the system. During the course of the study, the data base and technology subcommittees significantly improved the data base by validating the key data elements and providing, from private company files, data on additional reservoirs. In similar fashion, the screening models were validated/adapted for the study - a process which will ultimately provide TORIS much improved models. Further, three additional models not presently in the TORIS arsenal were developed by the NPC during the course of the study and will be provided to BPO at its conclusion. All this has been transmitted with the expressed understanding and expectation that the DOE will continue to maintain and improve the data bases and models after the NPC study is complete. This is a clear example of the process through which industry has input into TORIS.

## ENHANCED OIL RECOVERY

Question #8: Does industry have any input into your enhanced oil recovery program in terms of suggesting what areas may be of interest to them?

Answer: Yes, industry has a very real input in the definitional phases of our program, but so do others, including academic institutions and public sector organizations. Historically, representatives of all of these groups assisted in the development of the Management Plan for Enhanced Recovery, (ERDA, 77-15), which was published in 1977 and which formed the basis for selecting over 25 major cost-shared field tests. When DOE revised its petroleum research programs in 1981, and developed an updated Research Plan for Enhanced Light Oil Recovery, the document was sent to a broad cross-section of industry and others for review and comment. The responses were evaluated and many incorporated into the plan: the final document contains these comments, in a non-attributable form.

Another example of our broad interactions with industry, academia and public institutions is our continuing series of joint EOR Research conferences with the Society of Petroleum Engineers. DOE staff scientists and engineers work on the planning for these meetings and on selecting the actual research papers that will be presented. DOE sponsored research has always been well represented at these symposia. More recently, our intensive cooperative work with the National Petroleum Council in developing an updated study of EOR potential has given us a clear perception of industrial thinking on this subject. Also, peer reviews in program elements are held periodically where industry and academia are asked to review the research for relevance and quality. A peer review was conducted in the summer of 1983 on the University program.

The voluntary annual reports filed with us on several hundred EOR field projects are a major, though indirect, source of industry assessment. These projects were initiated under the EOR Tertiary Incentives Program are now beginning to yield important results. That industry responds so well on a purely voluntary basis verifies their belief in the value of reporting such information.

It should be noted that our programs are generally focused on very basic scientific issues that will lead, over the long-term, to a better understanding of the EOR resource and the processes for extracting it. Projects are selected on the basis of analyzing the significant discrepancies between what actually happens in the field and what laboratory work and theory predict. As such, our work complements rather than duplicates that which is conducted by industry.

The analytical base of the DOE program is quite broad and several public sector agencies have also suggested areas for work. The GAO, has expressed a need for an Information System for analyzing Federal tax treatment of marginal and off-shore oil production. Some states, particularly those experiencing financial problems because of declining petroleum production, have expressed similar interests. Within DOE, the Energy Information Agency has presented requirements relating to the future level of Enhanced Oil Recovery production.

While industry represents a major source of information and review in our program planning, the interests of other sectors is given equal consideration.

## ENHANCED OIL RECOVERY

Question #9: Previously a downhole steam generator was developed by Sandia. What is the progress toward commercializing this technology? What problems are there with the technology?

Answer: Two companies have followed up on the Sandia Downhole Steam Generator (DHSG) in an attempt to commercialize the technology. They have had some success in finding trial DHSG applications, but actual commercial production and use of generators is not yet occuring.

The Sandia unit ran for about 100 days total downhole at Long Beach. The unit suffered severe corrosion damage, which was determined to be the cause of the unit failing. Causes of the corrosion were sulfur coming from the diesel fuel used and free oxygen in combination with the relatively high combustion temperature. Sandia's metallurgical analysis suggests that fixes are possible using different materials. We do not know if the two companies (EES and Rocketdyne) experienced similar problems.

The present Sandia research program aims at evaluating the reservoir effects of DHSG gases, i.e., $N_2$, $CO_2$, $SO_x$ and $NO_x$. There may be benefits and/or drawbacks to having these gases directly injected into the reservior.

The Rocketdyne Division of Rockwell has also produced a DHSG and ran a two-week test with an oil company in California. There were apparently no problems with the test, but the duration was too short for any reliable evaluation. Rocketdyne believes their design will preclude any corrosion problems and will operate on lease heavy crude oil. In spite of these claims, it has been about 20 months since there has been any public knowledge of further Rocketdyne tests.

The major oil companies are still skeptical about the successful use of DHSG. The majority of current steamflood production comes from shallow fields where there is little or no benefit from a DHSG. The largest potential is in the Los Angeles area where depth, environmental and space/aesthetic limitations preclude conventional steam generation. We believe, however, that DHSG could have eventual widespread use in steamflooding if resource areas are found that are large enough for further development and commercialization. The L.A. area alone may not be a large enough resource for this to happen.

## OIL SHALE

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| Question #1: | In the FY 1984 appropriation, Congress directed the Department to reconstitute the oil shale program. What progress has been made to do that? How do you expect the program to change from what it was in FY 1983? |
| Answer: | The Office of Oil, Gas, and Shale Technology (Fossil Energy) has been actively re-evaluating the oil shale program for about three months. Discussions have been held with representatives in industry, academia, and with consultants. Also one "peer-review" has taken place on the "fracturing" part of the program. The validity and relevancy of existing goals and objectives are being examined as well as the effectiveness of the implementation plans previously structured. The review of the plan by the Administration has not been completed. Consequently, specific changes from the FY 1983 program are not yet available. The Oil Shale Program evaluation is expected to be completed within the next month, and its findings will be presented to Congress. |

## OIL SHALE

Question #2: How much money is included in FY 1984 and FY 1985 for work in Eastern oil shales? What projects are involved in this work? What technologies have been used in the Eastern oil shale area and what general results have been achieved with those technologies?

Answer: The FY 1984 Oil Shale funds include $750,000 specifically allocated to eastern shale research. These funds provide for the METC in-house program on fluidized bed retorting, environmental aspects, and support contracts. An estimated additional $1,700,000 of FY 1984 funds are expected to be utilized in eastern shale research contracts and related METC in-house work. Additional work at WRI (Western Research Institute), LANL, LBL, and PNL that is broadly applicable to fundamental questions about eastern and western shales environmental analysis is estimated to be $1,000,000 for eastern shales.

In FY 1985, an estimated total of $2,500,000 of the $12,000,000 budget request will be either directly or indirectly related to eastern shales.

In FY 1984, DOE eastern shale efforts at METC, WRI, and at several contractor facilities have the following objectives:

- To conduct in-house experiments with laboratory-scale retorts for the purpose of maximizing yield with concurrent minimization of operating costs and environmental impacts.
- To develop a retorting process data base to be used in upgrading both the process and its physical model.
- To verify innovative retorting processes through the "proof-of concept" stage.

- To develop an environmental, safety, and health research plan for Eastern oil shale utilization and implement research studies in support of this plan.
- To exchange technical information with state and private sector organizations working in Eastern shales.

Included in the above effort is a proposed cooperative agreement with the University of Kentucky Institute of Mining and Minerals Research to perform spent shale leaching studies using retorted Kentucky oil shale from the Dravo Traveling Grate retort.

WRI is completing a coring, characterization, and analyses program of shale from several midwestern states. Reports of the program evaluations will be available in FY 1984.

Ultrasystems, Inc. is completing a contract to investigate the potential of acid drainage in Eastern oil shale mines. This contract is part of a five-year plan to investigate the potential types and magnitudes of drainage problems resulting from the mining and processing of Eastern shales. A contract to investigate the reactions and products generated by Eastern oil shale processing waste is being negotiated.

Hycrude, Inc., is completing a preliminary environmental analysis of recently available data for the HYTORT oil shale retorting process. Data from 21 bench scale tests funded by Phillips Petroleum Company utilizing Indiana New Albany oil shale are being evaluated. The data are being analyzed for sulfur distribution, nitrogen distribution, gas trace constituents, product water composition, and spent shale leachate composition. The final report will be available in FY 1984.

Rockwell International completed, in FY 1984, an investigation into the application of hydropyrolysis to the hydroconversion of Eastern oil shales. Test results showed total carbon conversions as high as 70 percent and carbon conversions to liquids as high as 55 percent. The report is available through NTIS.

Battelle-Columbus Laboratories is completing a study to identify key operating parameters and to determine the feasibility of applying a conceptual process to retorting Eastern oil shales. The process is a multi-solids fluidized bed retort. The final report will be available in FY 1984.

Gulf Research and Development Company is completing an investigation into the application of a solvent hydrogen donor process for conversion of Eastern oil shales. The final report will be available in FY 1984.

Two firms proposed commercial ventures in Eastern Oil Shale to the Synthetic Fuels Corporation -- American Syn-Crude and Means Oil. American Syn-Crude proposed use of the Petrosix process (similar to the U.S. paraho process) developed in Brazil. This project was dropped from consideration in the fall of 1983. The Means project is being actively considered. The technology proposed is the Dravo circular grate retort using a method evolved from the iron ore wasting industry. Both systems heat the shale slowly relative to fluid bed or entrained bed systems where heat transfer is solid/solid rather than gas/solid. Research to date indicates far greater liquid recovery is realized with rapid heatup systems as evidenced by the work at METC and under the contracts with Rockwell and Battelle.

7. Mixing steam and/or inert gas with the injected gas improves recovery; however, more R&D is needed to optimize. (DOE and industry)
8. Inert gas generators are an effective and safe way to ignite a retort. A study on the optimum size of generator is needed.

## OIL SHALE

Question #5: Please provide the five year research and development plan for the chemistry and physics of oil shale retorting which was developed in FY 1983.

Answer: Attached is a copy of the five year plan that was developed in FY 1983 for research on the chemistry and physics of oil shale retorting.

OIL SHALE

Question #6: Please describe the results of the supercritical fluid extraction of Green River oil shale.

Answer: Organic matter extracted from Green River oil shale by supercritical extraction experiments was characterized by elemental analyses, number average molecular weight determination and field ionization mass spectrometry. The organic matter was also separated into fractions of organic acids, bases, and hydrocarbons. Characterizaton data demonstrated that the organic matter recovered in high yield from autoclave experiments is similar in composition to organic matter extracted in low yield at solvent reflux temperatures.

Total recovered organic materials were first characterized by field-ionization mass spectrometry. Selected samples were then separated to isolate fractions of organic acids, organic bases, neutral nitrogen compounds, and hydrocarbons. The acids and bases were characterized by elemental analysis and infrared spectrometry. Comparison of the amounts of acids, bases, neutral nitrogen compounds, and hydrocarbons recovered under different experimental conditons provides information pertinent to the mechanism(s) of the recovery processes. Also, the compositions of organic materials recovered at temperatures below 400°C are compared with the compositions of shale oils produced from pilot-scale retorting processes.

The organic matter extracted from the Green River oil shale in reflux temperature extraction experiments has a high hydrogen and oxygen content and an average molecular weight of between 500 and 600. Field ionization mass data indicate that the molecular weights of individual molecules range from under mass 200 to over mass 2000. The organic matter was separated into fractions of organic acids, bases, and hydrocarbons. The mineral content of the shale remained unaltered after the extraction experiments.

The organic matter recovered from shale in carbon dioxide/water autoclave experiments and methanol/water autoclave experiments between 300 and 400°C has, with the exception of nitrogen, an elemental composition similar to that of material recovered from reflux temperature extraction experiments. The number average molecular weight of the organic matter is between 450 and 600 amu as determined by VPO, and the molecular weights of individual molecules range from under 200 to over 2000. The organic matter recovered in these experiments was also separated into fractions of organic acids, bases, and hydrocarbons. Consistent with the elemental analysis data, higher percentages of acids and bases were recovered in the autoclave experiments than were recovered in the reflux temperature extraction experiments. Dramatic changes in mineral composition were observed to occur in experiments conducted at 375 and 400°C.

Characterization data demonstrate that the organic matter recovered in high yield from autoclave experiments is similar in composition to organic matter extracted in low yield at solvent reflux temperatures. Some differences in organic composition are observed, particularly nitrogen content, but the differences are not dramatic. Using the recovery data and characterization data described in these experiments, we conclude that one important mechanism involved in the recovery process involved partial dissolution of both organic and inorganic components of the shale as it is contacted with fluids such as methanol and water, in both liquid and supercritical states. Collapse of the shale matrix allows the complex mixture of organic molecules to be extracted. High recoveries of liquid organic matter are observed because pyrolysis reactions are not extensive at 400°C and only small amounts of organic matter are converted to gas or char.

The organic matter recovered at temperatures below 400°C are compositionally similar to shale oils; however, some significant differences in compound type do exist. Principal differences in composition are due to differences in thermal history of the products--organic materials recovered at temperatures below 400°C have been subjected to mild pyrolysis conditions, while retort-produced shale oils have been subjected to relatively severe pyrolysis conditions.

## OIL SHALE

Question #7: What are the specific process problems in oil shale production which need the most research or development? What are you doing to address those needs? What is industry doing in comparable programs?

Answer: The following are the key research needs identified in the Oil Shale program related to process:

1. Determining the effect of retort and post retort process conditions (i.e., heatup rate, temperature, pressure, retort environment, cool-down rate, vapor capture and cleaning apparatus, etc.) on the product yield and quality, and on the waste stream (gas, water, solid) composition and concentration.
2. Determining the chemical and physical stability of spent shale waste piles as a function of conversion (retort) and cleanup system design, placement procedure, and water composition (used for cool-down and compaction purposes — termed co-disposal as process waters are ususally used).
3. Establishing the criteria for effective in situ retorting, e.g., void volume, particle size distribution, permeability contrasts, interstitial particle composition, for shales of varying grades, composition and under varying overburden pressures.
4. Developing a predictive capability in terms of rubble induced (void, particle size distribution, permeability contrasts, etc.) as a function of geologic setting (grade, composition,

overburden pressure, natural fracture matrix) and explosive design (type, placement, sequencing).

5. Define the potential environmental impacts associated with in situ retort abandonment and strategies for mitigating the impacts.

DOE is doing the fundamental kinetics and chemistry to address item 1 and capturing the information in generic models that can be used by industry. In addition to retort modeling, sulfur evaluation and partitioning of trace metals (to the gas, water, solid or oil) as a function of retort condition is being examined. Improved diagnostics to characterize waste streams is also being pursued. Industry is applying the DOE information to the development of specific processes, using the data to support their design baseline.

DOE is conducting fundamental research in support of designing an integrated solid waste management research effort necessary to fully address item 2. The specific problems to be addressed are being defined and prioritized. Industry is also concerned about the potential problems associated with spent shale disposal. They have asked for DOE help in this area.

WRI is addressing item 3 and has made significant progress in the low/no overburden pressure situation. Results to date indicate effective retorting can be carried out in surprisingly low void volumes (8 to 12 percent).

SNL and LANL are addressing item 4 and have made significant progress. A model has been developed to predict the fractures induced by the early stress/shock waves. Work remains to verify this early time model and to address the subsequent phonomena of gas pressures causing partical motion. Industry has done some work on developing empirical models for specific site geologies.

DOE has not been active lately on item 5 (a number of abandonment strategies were developed and published two years ago) but is examining the prospects of doing some needed research at the C-a site where Gulf is faced with an in situ retort abandonment. Occidental has explored some retort abandonment strategies and conducted some leaching/cool-down experiments at Logan Wash, Colorado.

OIL SHALE

Question #8: Your justifications (p. 128) speak of the difficulty in purifying water containing the long chain aliphatic and polycyclic aromatic hydrocarbons unique to oil shale. What are you doing to resolve this problem?

Answer: Preliminary to control or mitigation of waste waters is characterization of the water, be it retort water (in situ), process water, condensate water, etc. The emphasis in the water treatment R&D is characterization of the refractory solutes which are not readily separable by existing physical, chemical, or biological methods.

Two basic approaches are available to the analyst for the routing quantitation of particular chemical classes or individual compounds in aqueous heterogeneous mixtures. The first approach quantitates solutes by methods of detection that are specific for individual chemical classes or particular compounds; many of these methods involve functional group derivations or clorimetric reactions that enable the compounds of interest ("analytes") to be distinguished from myriads of other solutes. Each analyte, however, requires a specific method of reaction and detection. The alternative approach employs an initial step that effects a sufficient degree of separation of the analyte from the mixture, and thereby enables the use of routine, nonspecific, bulk-property methods as means of detection.

Tremendous qualitiative differences can exist between quantitatively identical values obtained by any colligative-property method such as chemical oxygen demand (COD), dissolved organic carbon (DOC), or organic nitrogen. In oil shale wastewater treatment, for example, the removal of a large percentage of DOC may be inadequate if the toxicity, color, and odor of the wastewater are strictly associated with the remaining percentage. Identical values for any colligative properties can be greatly amplified, however, by the physical separation or "fractionation" of the sample matrix prior to the detection step.

The physical separation of chemcial classes is usually accomplished by "isolation" processes such as liquid-liquid partitioning (solvent extraction), ion exchange, or sorption (e.g., onto charcoal or macroreticular resins), and "concentration" methods such as lyophilization and ultrafiltration (Jolley, 1981; Leenheer and Farrier, 1979). The isolation schemes usually depend on various sequences of pH adjustment in the acidic, neutral, and basic ranges followed by extraction with water-immiscible solvents and back-extraction into aqueous phases, or passage of the sample through series of exchange resins or sorbents. The fractionated classes are combinations of acidic, neutral, or basic organic compounds. The analytes are then recovered from the various fractions by selectively removing the water or organic solvent. These procedures risk the chemical or physical alteration or contamination of the sample by introduction of solvents, acids, caustics, and heat. Although these methods are generally capable of effecting extensive separation of many different chemical classes, they are too time consuming for use in routine experiments or for monitoring waste treatment performance.

The oil shale program has developed several fractionation schemes and several analytical methods to qualitatively and quantitatively identify the compounds or compound types which constitute the refractory solutes. Most of the refractory organics are thought to be nitrogen heterocyclics, but the individual species are yet to be identified. A fractionation scheme, known as Reverse Phase Fractionation, has been developed to separate organics into hydrophilic and lipophilic fractions. The hydrophilic fraction contains mostly fatty acids (long chain oliphatic compounds); the lipophilic fraction contains mostly nitrogen-containing species, especially nitrogen heterocyclics and/or polycyclic aromatic hydrocarbons.

In parallel with the fractionation/characterization efforts are treatment efforts. Physical and chemical treatment schemes include filtration, steam stripping, coagulation, flocculation, reverse osmosis, adsorption, foam fractionation, air flotation, wet air oxidation, and ozonation. Biological treatment schemes include single and batch cultures, with and without ozonation and with and without ultraviolet irradiation. These characterization studies will continue for about five years, and will be followed by primarily control technology development.

## OIL SHALE

Question #9: Please describe the main projects in your environmental mitigation program for oil shale.

Answer: The environmental mitigation element of the oil shale program is divided into three areas of research: Air, water, and solid waste. Research in air, or gaseous emissions, is concentrated in characterization of emissions from laboratory scale retort simulators and from laboratory scale waste pile simulators. In FY 1984 a series of 10-ton retort experiments will be performed to characterize product gases before and after selected control techniques to remove hydrogen sulfide, particulates, and oil/water mist from the gas stream. This effort will result in better characterization and evaluation of use of industrial control of techniques for oil shale conversion emmissions. The Geokinetics, Inc. field retorts 27 and 28 are using sulfur removal equipment to evaluate sulfur control on a commercial scale process.

Research in water treatment was described in response to question 8. The present effort concentrates on waste water characterization regardless of process, i.e., surface, modified in situ, or tru in sity. The characterization emphasis will continue until sufficient information and data are available to concentrate on control techniques.

Research in solid waste management in FY 1984 is concentrated on development of a detailed research plan and also implementation of an already prepared codisposal plan. In FY 1985 implementation of the solid waste management plan will begin. Codisposal, or using process waste water to cool and compact a spent shale pile, is the concept envisioned by DOE and industry to solve two problems at one time. The waste water may need to be treated before codisposal. On a larger scale, the solid waste management plan will determine such issues as physical and chemical stability of piles, hydrology of water in piles and especially at the pile-air interface, climatological effects on piles, and other possible effects. Implementation of the solid waste plan will incorporate the codisposal work as a specific subset of tasks, and efforts will proceed in laboratory experiments, large scale outdoors experiments, and modeling.

## OIL SHALE

Question #10: How much of your funding is devoted to the development and improvement of models? What is industry's opinion of the usefulness of this data?

Answer: No specific dollar level can be assigned to the development and improvement of models because the modeling effort is integrated into every aspect of the oil shale program. Modeling is a critical part of technology development as well as of environmental mitigation. In FY 1984 a topical report will be prepared to summarize the modeling efforts in process chemistry, flow distribution, gas tracers, rock fragmentation, rock motion, environmental chemistry, air dispersion, hydrology, and system evaluation. All participants in the oil shale program have extensive modeling efforts which account for about one-fourth of the program budget. Models are essential tools in dealing with the complex chemistry and physics associated with oil shale research. The number of parameters dictates their use. Therefore, they are usually one of the deliverables upon completion of a research effort.

## OIL SHALE

Question #11: What are the main environmental and technological barriers to shale oil development?

Answer: The major barrier to shale oil commercialization is neither environmental nor technological, but rather a question of economics. As is the case with any resource, initial development will concentrate on the richest, most readily assessable portions of the resource base. There are no major technological nor environmental barriers in this area. The major concerns are the reliability and actual performance of systems now being deployed or designed and planned for near term commercial deployment. For example, uncertainty in the area of sulfur emissions control technology coupled with present crude air dispersion models has led to a range of estimates for the potential western industry size based on $SO_2$ regional standards of 200,000 to 800,000 barrels per day. Some present operating cost estimates for gas cleanup are as much as five times the operating cost of retorting, which encourages designing for retorting only the richest shale to reduce the amount of gas handled per barrel of oil produced. Similar economic considerations pertain to water and solid waste handling. Additionally, the actual pollutants and levels that may be found in various waste streams are in many cases only qualitatively identified or predicted as a result of both lack of understanding of how process variables effect emissions and inadequate measurement techniques. Some of these questions can only be answered through actual industry experience, which is expected to result in some modifications of present system designs. Others can be addressed through laboratory research, modeling, and systems analysis to provide pedigree quantitative data on how major generic system variables effect emissions and their regional dispersion. Beyond this, the rate of industrial development could be further restricted by the present estimated efficiencies of current environmental control procedures, as regional environmental emission standards "cap" further deployment of new or expanded facilities. However, for this to occur will require a major expansion of oil shale development beyond that currently planned.

## UNCONVENTIONAL GAS RECOVERY

Question #1: Please describe the division of activity between the Department of Energy and the Gas Research Institute in the unconventional gas area.

Answer: The activity pursued by DOE is based on the need for high quality information on the potential gas supply from unconventional resources in the high technical risk, long term research area. A further need is to increase the economic attractiveness of the resource to private industry with technology developments. Subprograms supported at DOE include the Western Gas Sands (lenticular), Eastern Gas Shales (Devonian and Ordovician), Geopressured Methane, and Environmental and Advanced Research (gas hydrates, deep source gas - subduction hypothesis coal bed methane). In the area of coal bed methane, DOE serves as technical advisor to GRI — DOE does not initiate activities.

The Gas Research Institute in turn emphasizes research to increase production levels from unconventional resources in the near term in areas where industry is almost, but not quite ready to move into. This requirement tends to concentrate activity in the most favorable areas of the resource and to accelerate the development of technology for recovery. GRI areas of interest include the Tight Gas Sands (Blanket), Eastern Devonian Shales, Methane from Coal Seams, Co-Production of Gas and Water from depleted reservoirs and Abiogenic Sources of Methane. In some cases, DOE and GRI programs together allow for comprehensive coverage of a resource, e.g., the Western tight gas sands formations. GRI is addressing the homogeneous blanket sand formations while DOE is exploring whether the dispersed, lenticular formations (which make up approximately 50 percent of the resource) can be recovered. The DOE effort entails extensive characterization of these reservoirs and testing of various stimulation designs.

## UNCONVENTIONAL GAS RECOVERY

Question #2: Please explain the rationale for the Eastern shale mineback facility and the GRI reasons for not providing funds to continue this project.

Answer: The Eastern gas shale mineback program has evolved from an assessment of the state-of-the-art problems of gas recovery from the Eastern Devonian Shales. Years of Devonian Shale research conducted under the direction of the Eastern Gas Shale Subprogram (EGSS) Office at DOE's Morgantown Energy Technology Center (METC), have focused on increasing recovery rates and maximizing recovery by developing improved stimulation techniques. Numerous field, laboratory, and theoretical stimulation studies have been conducted. The remaining major issues for developing the shale resource have been defined, and the mineback program has been formulated to address those specific recovery problems.

The Gas Research Institute, after expressing an early interest in cosponsoring a shale mineback, has currently refocused its program on near-term demonstrations of economic gas production in areas close to industry development and has delayed a decision on the mineback facility. The Department believes that development of a mineback facility should be a GRI responsibility.

## UNCONVENTIONAL GAS RECOVERY

Question #3: What particular research and development needs are left to address in the Eastern gas shales area? Is GRI involved in this area at all?

Answer: Remaining technical issues in the Eastern Gas Shales Subprogram focus on areas within the Appalachian, Illinois, and Michigan Basins where commercial production is non-existant, but the geology and geochemical paramenters show and the identification of potentially productive intervals within these areas (PA, NY, KY, WV, IN, IL, MI, VA, and TN). In addition there is a need to validate the models used to predict production performance from stimulated shale wells. Finally, uncertainty analysis and economic assessment are required to develop a reliable price/supply forecast for the basins.

GRI continues to support research efforts to advance rationales for exploration, to understand produciton mechanisms affecting recovery, and to develop improved stimulation/completion methods for lowering the costs of extraction. In many of these aress, GRI and DOE activities are complementary and provide more useful information to industry than either could alone. Noteworthy activities wherein this cooperation has already been visible is in the offset well test activities of DOE. More of the same is planned.

UNCONVENTIONAL GAS RECOVERY

Question #4: Please explain the reduced level of effort in Western tight gas sands and what, if anything, that does to the overall pace of the program.

Answer: The FY 1984 appropriation for Western Tight Gas Sands is $8,000,000. The FY 1985 budget request is $4,750,000. The FY 1984 allocation for the Multiwell Experiment (MWX) is $4,200,000, which includes two fracture stimulations plus all pre- and post-stimulation evaluations. The FY 1985 request includes approximately $3,400,000 for the MWX, which will include one stimulation plus pre-stimulation evaluation. Present plans call for three stimulations per two-year period. Experiments at the MWX facility are very much time constrained, in the sense that additional funding would not quicken the pace of stimulation research. The outyear funding requests (FY 1986 and beyond) for the MWX Experiment have not been finalized. It is anticipated that all planned efforts for the MWX Experiment will be completed. The lease agreement with Superior Oil was recently extended an additional two years to mid-1988.

The FY 1984 funding allocation for Western Gas Sands supporting research is $3,800,000. The planned FY 1985 allocation for supporting research is $1,300,000. FY 1984 efforts include work at the NTS Mineback facility, university modeling work, and some geophysical work. These efforts, although continuing into FY 1985, will be funded entirely with FY 1984 funds. In addition, Western Gas Sands laboratory research at NIPER in FY 1984 is not expected to continue into FY 1985. Some supporting research, namely geologic and modeling efforts, will be carried out at a reduced level in FY 1985 over FY 1984. This reduction in effort is not expected to seriously delay or effect the subprogram's future planned efforts or milestones.

## UNCONVENTIONAL GAS RECOVERY

Question #5: Fracturing of wells for gas stimulation has been going on for a long time. What is the state of the art in this regard? How easy of difficult is it to predict fracturing in various geological circumstances? What is your program doing to further this technology? Is there an organized data base that would allow the industry to more intelligently develop schemes to fracture in various geological areas?

Answer: The state-of-the-art in stimulation consists of injecting fluids and proppants at pressures and injection rates designed for optimum fracture extension and flow capacity. However, the ability to evaluate and predict the effectiveness of these current fracturing materials and techniques in unconventional gas reservoir geologies is still in its infancy, and is under active development in the UGR program. The interaction of fracturing materials with various formation types is being investigated along with the effect of natural fractures on reservoir and stimulation performance. These and other laboratory and conceptual studies are being used to develop a comprehensive predictive capability for stimulation effectiveness in unconventional gas reservoirs. As this capability is developed and verified in field trials, such as the Multiwell Experiment in tight western sands and the Offset Well test in eastern gas shale, the results are incorporated to organized data bases for each unconventional gas resource, as well as being transferred to industry for immediate use. This technology transfer is ongoing and has proved effective in generating industry development of unconventional gas resources.

## UNCONVENTIONAL GAS RECOVERY

Question #6: Please describe the potential of gas hydrates, their possible extent and when such resources might be expected to be available. What generically are the major problems foreseen in the production of such hydrates?

Answer: Potential resource estimates for gas hydrates range from 11 to 25,000 trillion cubic feet (TCF) (Meyer 1979, Dobrynin 1979) for onshore areas and from 2,700 to 6,700,000 TCF (McIver 1979, Dobrynin 1979) for offshore areas for the U.S. alone. Comparable world estimates are 500-120,000,000 TCF onshore (Meyer 1979, Dobrynin 1979), and 110,000-270,000,000 TCF offshore (McIver 1979, Dobrynin 1979). This potentially enormous resource is concentrated in both the Alaskan onshore and offshore, and the East, West, and Gulf Coast offshore areas. High grade target areas have been defined at Prudhoe Bay/Kuparuk (Alaska), and the New Jersey-Baltimore and Blake-Bahama Outer Ridge (East Coast Offshore) locations. Major problems that prevent extraction include: 1) uncertainty of resource estimates, 2) poor understanding of geological characteristics of hydrate occurrence, 3) lack of a proven production technology, 4) poor understanding of economic factors of recovery technology, and 5) uncertainty of legal (ownership in offshore areas) and environmental factors.

## UNCONVENTIONAL GAS RECOVERY

Question #7: What work is being done in deep source gas in your program?

Answer: The Deep Source Gas Project, in the Environmental and Advanced Research subprogram, is focusing research on activities to investigate the Plate Tectonic Theory for deeply emplacing ocean sediments into the earths crust and mantle. The project is not only investigating the configuration of these sediments at depth, but also the gas generating potential of these rocks. These investigations are being carried out by both in-house and contract research. During this initial stage of the project, most studies are geological in nature and are being carried out by the USGS, Texas A&M, and the University of Arizona. DOE is providing the funding for the Universities as well as the USGS efforts. The overall objective of these efforts is to establish the existance of natural gas arising from these deep depths, and connect their occurrances to conceptual models, define the limits of target areas, quantify the resource, and determine its significance to the nation's gas reserves.

## UNCONVENTIONAL GAS RECOVERY

Question #8: What new work is being done in coal bed methane stimulation?

Answer: DOE presently has a coal bed methane stimulation project underway in the Warrior Coal Basin of Alabama. This project is a jointly funded effort by DOE/GRI/U.S. Steel. An experimental well has been drilled, and in situ formation stress measurements have been obtained within and adjacent to the coalbed. DOE has utilized the initial stress measurements of the coal and barrier rocks to calculate the limiting values of stimulation injection rates and propagating pressures that will permit containment of the fracture patterns within the target coal seam. Stimulation of the target coal in the project well is scheduled for April 1984. Verification of containment will be accomplished by inspection of the stimulated zone in the coal seam after mining. This will occur in the late fall of 1984.

Approximately $100,000 is being requested for coalbed methane research work in FY 1985. The Department has identified several areas for coalbed reservoir property data, and stimulation design improvement. DOE's future research efforts in coalbed methane will focus on the deeper, unmineable coals, found for the most part in the Western U.S. The gas right ownership problems associated with these deeper unmineable seams are not thought to be any more difficult or different than normal gas and oil ownership problems.

## UNCONVENTIONAL GAS RECOVERY

Question #9: With regard to geopressured methane, is the data for methane production and its analysis being adequately covered by the geothermal program? What role do you have in advising on the need for and collection of data and its analysis? Is the $2 million deferred for this program being used to offset new budget authority requests in FY 1985?

Answer: The CE program emphasis is on the multiple objectives of thermal recovery and the co-production of gas. Significant engineering problems have been experienced with the design wells in the targeted geopressurized formations. Therefore, much of the effort and expenditure has been directed toward keeping the wells operable. Maintaining well operation, pumping down the reservoir, is an important activity in determining reservoir characteristics relevant to thermal and gas recovery. The CE intends to determine the gas recovery potential in the pursuit of their program. As agreed through discussion early in the fiscal year, Fossil Energy will serve in an advisory capacity to CE on gas recovery matters.

The $2,000,000 proposed for deferral is planned to be used to offset new budget authority requests for FY 1985.

DON FUQUA (Fla.), Chairman

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April 2, 1984

Hon. William A. Vaughan
Assistant Secretary for Fossil Energy
U. S. Department of Energy
Washington, D.C. 20585

Dear Mr. Vaughan:

Thank you for your testimony before the Subcommittee on Energy Develoment and Applications on March 7, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 20. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Kcw
attachment

Department of Energy
Washington, D.C. 20585

April 20, 1984

Honorable Don Fuqua
Chairman, Subcommittee on Energy
Development and Applications
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

On March 7, 1984, Assistant Secretary William A. Vaughan appeared before the Science and Technology Subcommittee on Energy Development and Applications to discuss the authorization for the fossil energy program.

Following that hearing, you submitted written questions for response to supplement the record. Enclosed are the answers to those questions.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

for Thomas H. Pretorius

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Ms. Christine Wegman

DON FUQUA (Fla.), Chairman

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April 2, 1984

Hon. William A. Vaughan
Assistant Secretary for Fossil Energy
U. S. Department of Energy
Washington, D.C. 20585

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I would appreciate your responses to the hearing questions by April 20. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Kcw
attachment

## SUBCOMMITTEE ON ENERGY DEVELOPMENT & APPLICATIONS
March 7, 1984

### Questions for Mr. Vaughan

General

1. In your FY 1985 budget request, you indicate that the Department plans to save $12.15 million in its fossil energy program based on new management initiatives. Would you please describe these initiatives, and how these savings affect the DOE fossil program?

2. What is the Department's position of the need to extend the various energy tax incentives to stimulate the development of a synthetic fuels industry?

3. As you know, the FY 1984 Supplemental Appropriations bill prescribes staffing levels for the Department's fossil program.

   Is your FY 1985 budget request in accord with these required staffing levels? If not, why not?

   Do you believe that thes programs can be responsibly managed at the requested levels? If so, please justify.

4. Are you planning to submit legislation to implement these reductions? If so, please provide the Committee a copy.

5. In your FY 1985 budget request, you suggest that the Department plans to use $49.189 million in prior year unobligated balances for its FY 1985 fossil program activities.

   Would you please discuss how you arrived at this figure, and please describe the programs that will be affected?

6. This is the first time you have testified before us. Would you please discuss any of the managerial or programmatic changes that you have made since you were appointed as the Assistant Secretary for Fossil Energy?

7. It is our understanding that the Liquified Gaseous Fuels Spills Test Facility will be totally funded by the private sector in the not-too-distant future. Please comment on the program.

8. There is widespread opinion that the Environmental Protection Agency interprets the Clean Air Act, as amended, relative to emissions reductions, to place primary responsibility on the consumer, for example a coal-burning utility. If that is so, it minimizes the motivation of a user to pay a premium for precombustion treated coal. Please comment.

## MHD

1. What indicators are there that you will get cost-sharing in the program as you have proposed?

2. MHD proponents have previously pushed for building a large-scale retrofit plant as part of the development process. What is your assessment of such a retrofit? When, if ever, would it make sense?

3. The FY 1985 budget request includes a proposed realignment in the MHD program. Please justify the anticipated 50-50 cost share relationship with industry.

## Liquefaction

1. What are the main research problems in liquefaction?
   What are you doing to solve them?

2. How can you adequately test processes without some larger scale facilities?

   Would industry be willing to scale-up from the bench scale data you produce in your programs?

## Combustion

1. As provided in a prior appropriation bill, you indicate in your budget request that there is a total of $30 million to be made available for the TVA AFB demonstration project this year and in upcoming years. What is the Department's evaluation of this project, and do you believe that it will meet project milestones and total cost estimates?

2. How can DOE encourage the demonstration of PFB technology?

## Heat Engines

1. Please explain your program for directly burning coal in turbines.

   What involvement is there by the turbine manufacturers?
   What are the major road blocks?
   What are you doing to solve them?

2. Why is a coal-burning turbine attractive compared to directly burning coal in a boiler, as is done in baseload coal utility plants?

3. Please explain the relationship and common problems among the technologies that would burn coal in a combuster for a turbine, use a PFB in conjunction with a turbine, and use gasified coal in a turbine.

   Which is most efficient?
   Which is easiest technically?
   Which is closest to becoming commercially feasible?

## Fuel Cells

1. What is the status of the 4.8 Megawatt fuel cell facility at Con Edison in New York City?

   Do you have any idea how much it would cost to refurbish the facility?

   What are the major alternatives for the use of the facility?

   What is the R&D benefit from extended use of the facility after refurbishment?

2. What are the main problems that the technology development programs in phosphoric acid are addressing?

3. What are the main technological problems with molten carbonate and solid oxide technology?

   What are the main benefits?

   Is it likely that they would be commercialized if the phosphoric acid fuel cell is not?

4. Testimony received from witnesses on March 6, 1984 by this Subcommittee indicated that the proposed FY 1985 budget for fuel cells is a drastic reduction from the FY 1984 appropriation level. Please justify this action.

Coal Cleaning

1. What types of coal cleaning processes do you expect to investigate in your proposed cooperative program with the Electric Power Research Institute at their facility in Homer City, Pennsylvania?

   Do you expect to do chemical coal cleaning there also?

2. How much will clean coals cost in comparison to other fuels?
   What are their projected uses?

3. It is possible that a meaningful proof-of-concept project for chemical coal cleaning could involve substantial sums of money. To what extent does the Fossil Energy Program anticipate such an occurrence?

## Control Technology (Acid Rain)

1. What are the most promising techniques for combined nitrogen and sulfur oxide removal in coal burning facilities?

   When do you expect any of these technologies to become commercial?

   What are the advantages of these systems over normal scrubbers?

## Combustion

1. What types of coal combustors are you working on and why?

   Will they reduce nitrogen and sulfur oxide emissions?

   Will they allow the use of coal in turbines?

   Will they be able to be used in industrial applications instead of scrubbers in order to reduce emissions?

## Coal Gasification

1. Please explain the major features of the gasifier at Waltz Mill, Pennsylvania.

   What is the status of that facility?
   Could a useful program be developed to use that facility?
   Is the Gas Research Institute still interested in this gasification process?

2. What is the Department's evaluation of the need for an advanced surface coal gasification program at the Waltz Mill facility in Pennsylvania?

3. What is the status of the Great Plains Coal Gasification Project? Do you believe that this project is on schedule and within cost estimates?

   Please provide a breakdown of the $3 million which you request for managing the Great Plains Coal Gasification Project.

Oil Shale

1. In your budget request, you indicate that Eastern oil shales are currently receiving increased industrial interest. How is this development reflected in your proposed oil shale program for FY 1985? Do you believe the program is well-balanced to reflect the potential of both Eastern as well as Western oil shales?

Unconventional Gas Recovery

1. Please explain the separation of responsibilities between the Gas Research Institute and DOE in unconventional gas recovery.

2. Why does the Department have no program in coal-bed methane recovery?
Is it commercial?
Is additional R&D necessary?

3. In your budget request for FY 1985, you indicate that the Department has submitted a deferral request for all activities relating to geopressured methane in the DOE fossil program. However, do you believe that it might be reasonable to consolidate all of the Department's unconventional gas programs, including the geopressured program, within one central office? If not, why not?

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## GENERAL

Question #1: In your FY 1985 budget request, you indicate that the Department plans to save $12.15 million in its fossil energy program based on new management initiatives. Would you please describe these initiatives, and how these savings affect the DOE fossil program?

Answer: The $12,150,000 in savings for FY 1985 is comprised of management initiatives in Financial Systems Reform and Administrative Organization Management.

### Financial Systems Reform

This initiative will result in savings of $12,000,000 in FY 1985 through improved management of the deobligation of multi-year funds. Deobligations may occur due to contract close-outs, contractor defaults, or other instances of contractual dollar reductions, such as cost disallowances based on audit results. Under this initiative, such deobligations will be reported and evaluated to determine whether or not the funding should be retained in the program area where it was originally appropriated. If it is determined that there is no compelling reason to retain these funds in that program area, they will be deferred, if necessary (i.e., FY 1984 and previous year funding), and used to offset budget authority in FY 1985.

### Organization and Management

This initiative will result in savings of $150,000 resulting from improved planning and control of organization structures within the Office of Fossil Energy. The implementation of this initiative will include guidance to managers on improved organization planning and special reviews of existing and proposed organization structures focusing on supervisor to employee ratios, reduction in the number of levels of supervision, and overall staffing resource utilization. The reduction in budget authority represents manpower savings.

HS&T (Fuqua)
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## GENERAL

Question #2: What is the Department's position of the need to extend the various energy tax incentives to stimulate the development of a synthetic fuels industry?

Answer: Certain tax incentives were established in the 1970's to stimulate the development of selected resources and fuels. The Business Energy Tax Credit, which bestows an additional 10 percent tax credit on top of the investment tax credit to qualifying projects, is most applicable to this question because the deadline for applying for this tax credit (based on having completed certain permit-related activities) expired at the beginning of 1983.

The Department generally favors energy tax credits as a tool of energy policy. However, the Department believes that expiration of the business energy tax credit has not had an adverse effect on domestic energy development.

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GENERAL

Question #3: As you know, the FY 1984 Supplemental Appropriations bill prescribes staffing levels for the Department's fossil program. Is your FY 1985 budget request in accord with these required staffing levels? If not, why not? Do you believe that these programs can be responsibly managed at the requested levels? If so, please justify.

Answer: The FY 1984 staffing level of 737 FTE's complies with the Congressional floor of 715 FTP employees mandated by Public Law 98-63.

The staffing levels proposed in the FY 1985 budget request are not in accordance with the staffing levels mandated in the FY 1984 Supplemental Appropriations bill for Fossil Energy. However, we believe the FY 1985 proposed level of 637 FTE's provide the level of personnel considered necessary by the Department to effectively manage the Fossil Energy Program. The Department believes the Fossil Program can be effectively managed at the 1985 budget request staffing levels through increased management efficiencies implemented in the following areas:

- The conduct of appropriate A-76 studies of certain support functions that recommend providing services by contract rather than in-house.
- Reducing requirements for other-than-full-time permanent temporary positions.
- Increasing administration efforts to reduce the number of mid and senior level positions.
- Improving efficiencies through the use of automated word processing and improved business management systems.

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## GENERAL

Question #4: Are you planning to submit legislation to implement these reductions? If so, please provide the Committee a copy.

Answer: In order to achieve the personnel levels requested in the Fossil Energy Congressional Budget Request, it is expected that legislation will be enacted to repeal or revise the employment floors in Public Law 98-63. The Department has requested such legislation to repeal minimum personnel levels (floors) mandated by Congress in provisions appended to various appropriation acts (see attached). Until Public Law 98-63 is changed, however, Fossil Energy will of course comply with the legislative requirements regarding personnel levels.

# A BILL

To repeal personnel restrictions applicable to the Department of Energy.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 303 of the Supplemental Appropriations Act, 1982 (Public Law 97-257) and the item entitled "Administrative Provisions, Department of Energy" and its heading "DEPARTMENT OF ENERGY" in chapter VII of the Supplemental Appropriations Act, 1983 (Public Law 98-63; 97 Stat. 328) are repealed.

SEC. 2. The final proviso in section 101(g) of the Continuing Appropriations for Fiscal Year 1983 (Public Law 97-276) and the final proviso in section 101(f) of the Continuing Appropriations for Fiscal Year 1983 (Public Law 97-377), both concerning Department of Energy employment levels, are repealed.

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GENERAL

Question #5: In your FY 1985 budget request, you suggest that the Department plans to use $49.189 million in prior year unobligated balances for its FY 1985 fossil program activities. Would you please discuss how you arrived at this figure, and please describe the programs that will be affected?

Answer: The $49.189 million in prior year unobligated balances to be used in Fossil Energy's FY 1985 budget request was determined after a careful analysis of all available FE funding. A summary of the programs included in these balances is as follows:

o Coal Loan Guarantee funds appropriated under the Energy Production, Demonstration and Distribution Account (89X0219) are deferred as no qualified applications have been identified. These funds ($2,500,000) are proposed for transfer to the Fossil Energy account as an FY 1985 offset.

o The total deferred in FE Construction projects is $37,196,000. The majority of funding in this area is a result of $23.2 million of SRC-II funds being made available as a result of reimbursement of funds contributed by the governments of West Germany and Japan. An additional $10.7 million in this project is available due to termination activities in this project. Also, included in these amounts is $2.0 million associated with the SRC-I demonstration plant. The remaining funds ($1.295 million) in construction are a result of terminations in the High-Btu Pipeline projects and the Low/Medium-Btu Pilot Plant.

- FE Operating Expense deferrals total $9.493 million. This deferral consists of three major components: $2,750,000 of unobligated prior year funds; $2 million appropriated in FY 1984 for geopressured methane research activities which duplicate research funded in the Geothermal Energy program; and $4.743 million in reimbursements from the foreign contributions to the Solvent Refined Coal (SRC-II) demonstration project.

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GENERAL

Question #6: This is the first time you have testified before us. Would you please discuss any of the managerial or programmatic changes that you have made since you were appointed as the Assistant Secretary for Fossil Energy?

Answer: I have been on-board as the Assistant Secretary for Fossil Energy for approximately 75 days. During this time, I had an extensive senior management meeting of headquarters and field personnel at which the overall Fossil Energy R&D program and significant issues regarding this program were reviewed and discussed. I was impressed with the way this program was being managed and, therefore, saw no need to make any managerial changes. I also visited the two Energy Technology Centers for in-depth programmatic briefings and was satisfied with the manner in which the programs were being executed. I plan to visit the Bartlesville Project Office in the near future. The management systems in place have worked well in the past for Fossil Energy and, therefore, I intend to continue them.

The only change that I have instituted is to have pertinent Fossil Energy documentation come to my office for review so as to allow me to become more familiar with the program. I have made no programmatic changes because I am still in the process of learning the program. Until this learning process is completed to my satisfaction, I do not intend to make any changes. I might add that we are now in the process of testifying on the FY 1985 budget, while at the same time executing the FY 1984 appropriation and developing the FY 1986 budget proposal. These are busy times for Fossil Energy and I believe the morale of our employees is very high.

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GENERAL

Question #7: It is our understanding that the Liquefied Gaseous Fuels Spill Facility will be totally funded by the private sector in the not-too-distant future. Please comment on the program.

Answer: Comments regarding the current status of the Liquefied Gaseous Fuels Spill Test Facility Program are as follows:

On March 1, 1984, the Department of Energy designated a section of the Nevada Test Site, in Nye County, Nevada, as the site most suitable for the location of the Spill Test Facility. The site is within a natural geological basin, named the Frenchman Flat Basin, which extends from the Nevada Test Site eastward into the adjacent Nellis Air Force bombing and gunnery range. The site was designated after a screening of 69 Federally-owned sites within the continental United States.

Site preparation and long-lead procurement activities will be funded with prior year appropriations. FY 1985 funding ($2M has been requested) will be used to complete fabrication and begin checkout tests of the facility. These activities will include the development of approval processes and procedures for environmental documentation of future tests. The funds will also be used to develop the information necessary for obtaining state and other required permits and for performing safety analyses to assure personnel and equipment safety.

Once the Spill Test Facility is completed and operational, the Department of Energy plans to make it available, on a user fee basis, to private firms and other Federal, state and local government agencies. Some federal funding will be required to provide maintenance and management support activities related to the facility.

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GENERAL

Question #8: There is widespread opinion that the Environmental Protection Agency interprets the Clean Air Act, as amended, relative to emissions reductions, to place primary responsibility on the consumer, for example a coal-burning utility. If that is so, it minimizes the motivation of a user to pay a premium for precombustion treated coal. Please comment.

Answer: The Clean Air Act, as amended, encompasses three emission control standards for coal burning utility plants. Those plants for which construction has been completed or commenced before August 17, 1971, must meet standards set by individual states -- State Implementation Plans (SIPs). Plants constructed, or for which construction had commenced between August 17, 1971, and September 18, 1978, must comply with the more stringent of (1) SIPs, or (2) the 1.2 pounds of $SO_2$ emission per million Btu of heat input required by New Source Performance Standards (NSPS). Individual utilities have the latitude to meet applicable SIPs or the NSPS by whatever method they may choose such as fuel switching, precombustion treatment of coal to reduce sulfur content, use of scrubbers, or any combination thereof.

The most recent amendment of the Clean Air Act requires that $SO_2$ emissions from coal burning utility plants for which construction commenced after September 18, 1978, be reduced a minimum of 70 percent through a system of continuous emission controls. The percent reduction is computed on the basis of overall $SO_2$ removed by all types of $SO_2$ and sulfur removal technology, including scrubbers and fuel pretreatment systems such as coal cleaning. No credit is given for $SO_2$ emission reductions resulting from fuel switching. However, sulfur removed by a coal pulverizer or in bottom ash and fly ash may be included in the computation.

It is clear that a coal-burning utility has a menu of approaches available to meet the emission standards, including precombustion treated coal.

The decision of which approach to use will vary by plant and which standard must be met.

### MHD

Question #1: What indicators are there that you will get cost-sharing in the program as you have proposed?

Answer: Discussions with interested parties in the private sector are now in progress regarding both program direction and cost-sharing. Although no firm commitments have yet been made, some cost-sharing appears to be possible. It is difficult to be any more specific at this time.

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## MHD

Question #2: MHD proponents have previously pushed for building a large-scale retrofit plant as part of the development process. What is your assessment of such a retrofit? When, if ever, would it make sense?

Answer: The proposed integrated MHD system is believed to be an essential step toward the ultimate commercialization of MHD technology. A large scale retrofit may be the next logical step, pending the satisfactory operation of the smaller facility.

Question #3: The FY 1985 budget request includes a proposed realignment in the MHD program. Please justify the anticipated 50-50 cost share relationship with industry.

Answer: The 50-50 cost-share relationship is DOE's position regarding a reasonable government/industry partnership in the further development of MHD technology. The final cost-sharing relationship will depend on the results of government/industry discussions and agreements regarding program direction and technical risks.

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# COAL LIQUEFACTION

Question #1: What are the main research problems in liquefaction? What are you doing to solve them?

Answer: For the foreseeable future the principal deterrent to the use of coal liquefaction to augment the domestic supplies of liquid fuels is process economics. High capital and operating costs per unit of output result in synthetic liquid fuel product costs that exceed the world oil price. To help to reduce the product costs, our program is focussed on R&D that will increase product selectivity and quality, simplify liquefaction process systems and enhance efficiency and operating reliability. Advances in these areas will lead to lowered cost of production and promote the use of coal liquefaction technology. All existing projects address the issue of lower costs. Examples include investigations of staged operations to reduce temperature and pressure requirements, and of improvements in catalysis to selectively produce more desirable liquids while producing less material which requires additional processing.

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## COAL LIQUEFACTION

Question #2: How can you adequately test processes without some larger scale facilities? Would industry be willing to scale-up from the bench scale data you produce in your programs?

Answer: In the smaller scale laboratory and bench-scale R&D planned for our coal liquefaction program, it is possible to examine the scientific and technical improvements which can lead to reduced product costs, improved product yield and quality and reduced environmental impacts. There are engineering issues, of course, which must be resolved at a larger scale. In some instances, the work previously done on similar processes at larger scale (up to 200 ton per day pilot plants) could be sufficient to allow scale-up from the bench scale, but it is quite likely that significant improvements would require additional scale-up studies. It is our position that private industry is better able to select process technology and plan its development at larger scales. Therefore, we believe that industry should take the lead on projects to move liquefaction technology forward when market forces indicate the need.

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## COMBUSTION SYSTEMS

Question #1: As provided in a prior appropriation bill, you indicate in your budget request that there is a total of $30 million to be made available for the TVA AFB demonstration project this year and in upcoming years. What is the Department's evaluation of this project, and do you believe that it will meet project milestones and total cost estimates?

Answer: As you are aware, the Tennessee Valley Authority is developing AFB technology for utility applications, and DOE is pursuing industrial applications. Both DOE and TVA continue to exchange basic and applied research data in order to assist our respective programs. As the TVA demonstration project is not under DOE control, we are unable to offer an evaluation of the specific schedule and cost estimates. Fossil Energy has been briefed on the project by TVA; however, the information provided is preliminary since the project is still in the design phase.

It should be noted that in FY 1984, Congress appropriated $15 million for FY 1985 and $15 million for FY 1986 in cooperation with TVA and the Commonwealth of Kentucky for the planning, designing, constructing, operating and testing of the TVA AFB demonstration project. DOE has no management role in this project, but will be apprised of events in the development and operation of the facility.

DOE, in its desire to develop a coordinated two-year research plan with TVA and EPRI, is working closely with both organizations to assist in the development of test plans that support DOE's needs without compromising the TVA effort. To initiate and facilitate this development, it is planned that DOE will request data such as:

- Demonstration design and process parameters.
- Pilot plant data used in establishing the parameters.
- Start-up and operational schedule.
- Operating cost estimate for the demonstration plant.
- Preliminary test plans, goals, objectives, and activities to be undertaken.
- Final test plans.
- Monthly reports.
- Special or topical reports on component performance, unexpected events, etc.
- System optimization studies.
- Economic assessment of a commercial plant.
- Analysis of all feedstocks and wastes.
- Backup samples for DOE of solid samples from particulate cleanup systems, the FBC bed and feedstocks.
- Assessment of the environmental significance of gaseous/particulate emissions, solid wastes, and performance of emission control systems.

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COMBUSTION SYSTEMS

Question #2: How can DOE encourage the demonstration of PFB technology?

Answer: DOE is cooperating with industry by providing the performance and subsystem data from Government sponsored test facilities, and jointly funding those critical component/subsystem developmental areas impeding PFB commercialization. The results of component testing along with generic data obtained from the testings will establish the PFB technology data base. The data thus developed will be in sufficient detail so that the private sector can proceed with PFB commercialization.

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## COMBUSTION

Question #3: What types of coal combustors are you working on and why? Will they reduce nitrogen and sulfur oxide emissions? Will they allow the use of coal in turbines? Will they be able to be used in industrial applications instead of scrubbers in order to reduce emissions?

Answer: In the Combustion Systems activity, technology development utilizing coal combustors are in three main areas: Atmospheric Fluidized Bed Combustion (AFB), Pressurized Fluidized Bed Combustion (PFB), and Advanced Combustion Technology, where the advanced combustor program is located.

The focus of the AFB combustion program is to investigate innovative fluidized bed combustion technologies designed to reduce capital and operating costs by 30 to 50 percent over conventional AFB costs.

The PFB combustion program objective is to develop PFB combustion systems that achieve high combustion efficiency and acceptable component durability and reliability while staying within acceptable emission levels.

The advanced combustor efforts are contained in the Advanced Combustor Technology subactivity where the Advanced Combustor program is located. The primary objective of the Advanced Combustor program is to develop a technology for retrofit to existing oil- and gas-fired boilers which will permit coal combustion. The Advanced Combustor concept is intended to remove the coal ash prior to combustion in the boiler, while simultaneously incorporating the means to reduce emissions of oxides of nitrogen and of sulfur in order to satisfy environmental requirements. The device will accommodate a wide range of grades and types of conventional pulverized coal, coal-water mixtures (CWM), or beneficiated coal-water mixtures (BCWM).

The "partially developed" concepts effort is competing two combustors against each other for retrofit to utility and larger industrial boilers for which they appear to be most effective economically, while the five "innovative concepts" contracts offer the most promise to ultimately yield a technological development which would enable the advanced combustor to be practical for retrofit to smaller industrial boilers, commercial facilities, and perhaps even residential applications.

With regard to air quality aspects of the advanced combustor, emissions of oxides of nitrogen appear to readily meet existing utility or proposed industrial New Source Performance Standards (NSPS). An important objective of the Program is to be able to meet NSPS for $SO_2$ without the use of flue gas desulfurization (FGD) by enhancing sulfur removal during combustion. The goals of the Advanced AFB program are to have a minimum $SO_x$ removal of 90 percent, maximum $NO_x$ emissions of .4 lb/$10^6$ BTU and maximum particulate emission of .03 lb/$10^6$ BTU. PFB has the capability for removing 98 percent of the sulfur in the coal. Nitrogen oxides formation consisting mostly of "fuel $NO_x$" is also well below current NSPS standards because the low bed (combustion) temperature does not favor the production of "thermal $NO_x$".

With regard to the use of coal in turbines, the present AFB and advanced combustor programs do not envision this application as one of their objectives. However, this does not preclude the possibility that one of the concepts will show promise in this regard. Application of pressurized fluidized bed combustion to utility powerplants will be through a gas turbine combined cycle powerplant or configuration.

If the Combustion Systems program is successful, Advanced Combustors will be able to be used in industrial applications instead of scrubbers in order to reduce emissions. DOE's Atmospheric Fluidized Bed program is totally directed for industrial/commercial boiler applications. AFB technology eliminates the need for scrubbers but a baghouse dust collector is required. The PFB program is directed to eliminate the need for scrubbers in the utility sector, however a baghouse may be required to meet NSPS particulate emissions standards.

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## HEAT ENGINES

Question #1: Please explain your program for directly burning coal in turbines. What involvement is there by the turbine manufacturers? What are the major road blocks? What are you doing to solve them?

Answer: We are in the preliminary stages of evaluating the combustion of coal water slurries under gas turbine engine operating conditions and assessing the probable effects of impurities, present in the coal fuel, on turbine performance.

The turbine manufacturers are involved in the initial combustor design development work and in the evaluation of impurity effect on turbine performance.

The major road block is the adverse effects of fuel impurities, especially the alkali metals (potassium and sodium, combined with other species). The constituents, even in very small concentrations, can produce major problems in fouling or damaging turbine surface by deposition, corrosion or erosion.

We are attempting to improve the quality of the fuel by coal beneficiation; to mitigate turbine damage by advanced cooling techniques; and to remove impurities from the gas stream before it gets to the turbine by various hot gas cleaning methods and advanced combustor designs.

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## HEAT ENGINES

Question #2: Why is a coal-burning turbine attractive compared to directly burning coal in a boiler, as is done in baseload coal utility plants?

Answer: A coal-burning turbine lends itself to baseload combined cycle systems in which a steam generator can be piggy-backed to the turbine exhaust. More electricity can be produced from a ton of coal this way. A combined cycle system of this kind is potentially capable of achieving efficiencies in the mid-to-high 40% range as compared to 35-37% for a new, modern simple steam cycle. The potential benefits are both economic and environmental. Also, the turbine must not be thought of only in terms of utility baseload duty. It also can play a major role in utility peaking duty. Industrially, it is of particular importance in chemical, metals, paper and other energy intensive segments of the economy that need both electrical and thermal outputs. This aspect of its importance to the U.S. industrial scene has been heightened by recent regulatory revisions, i.e., PURPA.

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HEAT ENGINES

Question #3: Please explain the relationship and common problems among the technologies that would burn coal in a combuster for a turbine, use a PFB in conjunction with a turbine, and use gasified coal in a turbine. Which is most efficient? Which is easiest technically? Which is closest to becoming commercially feasible?

Answer: The problems of burning coal directly was explained in Question #2. A PFB presents a similar general kind of problem as far as the turbine is concerned and the product gases from the PFB will not meet the quality standards of conventional gas turbines. Thus, the turbine cooling mentioned earlier, is equally applicable. The PFB could be expected to produce "dirtier" combustion gases for the turbine to handle than a highly beneficiated fine coal fired directly. A PFB option, which would greatly increase capital cost, is to put a large heat exchanger in the PFB and heat the compressor discharge air to 1300° or 1400°F. This concept lends itself to a combined cycle and has been studied. The gasifier coal concept is somewhat different than either of the other technologies because the product gas can be cleaned hot before it goes to the combustor. This is a big advantage because only a fraction of the volume of "gas" is handled compared to the other technologies. The concept is to clean up the gas hot to avoid the heat losses and capital investments that go with cold gas "scrubbing" (to remove alkali, sulfur, and particulate).

The direct fired system could be potentially the most efficient, but there are too many variables to make a judgement at this time.

On the basis of where we are and what we know, the gasified coal approach appears to be the easiest technically.

Using gasified coal in a turbine would be the technology which is closest to becoming commercially feasible.

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## FUEL CELLS

Question #1: What is the status of the 4.8 Megawatt fuel cell facility at Con Edison in New York City? Do you have any idea how much it would cost to refurbish the facility? What are the major alternatives for the use of the facility? What is the R&D benefit from extended use of the facility after refurbishment?

Answer: On March 28 the damaged fuel cell stack was replaced and procedures for power operation startup were initiated. Several attempts to achieve power operation have been unsuccessful. The problems preventing successful startup have included failure (and replacement) of a Thermal Management System pump and control system logic anomalies. Additional startup attempts are continuing.

The Department has not considered any actions regarding the refurbishment or alternative use of the facility and cannot make any cost estimates at this time. We are also unaware of any specific EPRI or Consolidated Edison plans for refurbishment or alternative use of the facility. The refurbishment of the existing 4.8 MW powerplant would probably not provide any significant additional R&D data or information beyond that being obtained from the 4.8 MW Tokyo Electric Power Company powerplant and the expected information from the existing 4.8 Mw Consolidated Edison Company powerplant.

HS&T (Fuqua)
Subc. on Energy Devt.
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March 7, 1984 Hearing

# FUEL CELLS

Question #2: What are the main problems that the technology development programs in phosphoric acid are addressing?

Answer: The main problems in phosphoric acid fuel cell technology development include (1) achieving the electrochemical performance levels demonstrated in small laboratory components with materials and component sizes suitable for prototype powerplants, and (2) achieving lifetimes necessary for acceptable life cycle costs (which primarily involves materials corrosion and operating refinements).

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## FUEL CELLS

Question #3: What are the main technological problems with molten carbonate and solid oxide technology? What are the main benefits? Is it likely that they would be commercialized if the phosphoric acid fuel cell is not?

Answer: The molten carbonate and solid oxide technology development programs are addressing critical cell and short stack design and materials problems. Ongoing R&D efforts include the following:

### Molten Carbonate Fuel Cells

- Electrodes with improved stability in pressurized cells
- Improved electrolyte control for longer life
- Verifying internal reforming with natural gas for high efficiency and reduced cost.

### Solid Oxide Fuel Cells

- Achieving performance levels of single cells in larger modules
- Verifying life projections
- Developing cell and system design consistent with future applications.

The primary benefits of molten carbonate and solid oxide fuel cells over phosphoric acid systems is higher system efficiency potential, particularly with internal fuel reforming at their higher operating temperatures, and possibly greater tolerance to impurities in coal derived fuels. The higher system efficiencies may also serve to reduce system costs.

It is premature at this time to speculate on the commercialization of molten carbonate fuel cells. The technology has not advanced beyond the early R&D stages -- testing on single cells and test of a few short stacks. These verification tests indicate that design and materials problems exist, and the successful resolution of these cannot be forecast at this time. Solid oxide fuel cell development is behind that of molten carbonate systems.

Any problems encountered in developing or commercializing phosphoric acid fuel cells could impact the development, user acceptance, or the commercial application of the more advanced fuel cells.

HS&T (Fuqua)
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March 7, 1984 Hearing

## FUEL CELLS

Question #4: Testimony received from witnesses on March 6, 1984 by this Subcommittee indicated that the proposed FY 1985 budget for fuel cells is a drastic reduction from the FY 1984 appropriation level. Please justify this action.

Answer: Although the Department's request for FY 1985 does represent a substantial reduction below the FY 1984 appropriation, the Department believes that the budget request provides adequate resources to support essential commitments and continue essential high risk, high payoff technology development activities.

The FY 1985 funding level is sufficient to continue the fuel cell technology base program. The 40 kw field test project and the 4.8 Mw demo in New York City are fully funded and do not require FY 1985 funding. The phosphoric acid fuel cell development activities have progressed to the point where it is appropriate for the private sector to assume a greater financial burden in moving the technology into the commercial marketplace. As a result, federal funding is being reduced in the phosphoric acid area. Although the molten carbonate technology development program is continuing to make progress, cell design and material difficulties have forced delays in stack fabrication and test verification activities. As a result, particularly in the absence of significant program cost-sharing, it is technically appropriate and cost effective for FY 1985 to continue only one stack development effort and supporting materials R&D. The requested funding for solid oxide fuel cells is essentially at the same level as FY 1984.

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CONTROL TECHNOLOGY & COAL PREPARATION

Question #1: What types of coal cleaning processes do you expect to investigate in your proposed cooperative program with the Electric Power Research Institute at their facility in Homer City, Pennsylvania? Do you expect to do chemical coal cleaning there also?

Answer: The cooperative program being planned with the Electric Power Research Institute is intended to select and test advanced physical coal cleaning concepts at the proof-of-concept scale. The systems to be tested will be selected on the basis of their ability to significantly reduce coal sulfur and ash content while retaining high BTU recovery and economics comparable to today's technology. It is hoped that these improved systems, when commercialized in the near term, could provide industry with a cost effective alternative for reducing acid rain precursor emissions. No chemical coal cleaning systems will be tested as a part of this cooperative program. The stage of development of chemical cleaning systems precludes them from being a part of this particular program.

HS&T (Fuqua)
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CONTROL TECHNOLOGY & COAL PREPARATION

Question #2: How much will clean coals cost in comparison to other fuels? What are their projected uses?

Answer: Estimates for the cost of the clean fuels being developed through the DOE Coal Preparation program and a cost comparison to the fuels they would replace are shown on Figure III. These fuels would be produced by physical, chemical or combination physical/chemical cleaning processes. Estimates of these processing costs are shown on Figure II.

| CLEANING TECHNIQUE | POTENTIAL | | | FUEL | QUALITY | | | | | ESTIMATED | | | | COSTS | | APPLICATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RANGE | | | AVERAGE | | | | η | | COAL | CAPITAL | O&M | | PRODUCT | PROCESSING | |
| | ASH% | SULFUR% | | ASH% | SULFUR% | | | | | ($/MMBtu) | ($/MMBtu/Hr) | ($/MMBtu) | | ($/MMBtu) | | |
| | | | | | P | O | | | | | | | | | | |
| I NONE | 8-40 | 5-10 | | 20 | 1.9 | 1.1 | | -- | | 1.20 [1]<br>2.10 | -- | -- | | -- | -- | Coal Designed Electric Utility |
| II Commercially Available (14 Mesh x 0) Gravity, Heavy Media, Flotation | 6-10 | 3-8 | | 10 | 0.9 | 1.1 | | 95 [2]<br>90 | | 1.20<br>2.10 | 300 [3]<br>1400 | 0.13<br>0.18 | | 1.43<br>2.57 | 0.23<br>0.47 | Coal Designed Utility<br>Oil Designed Utility & Industrial Boilers<br>Blast Furnace |
| III Limited Physical (200 Mesh x 0) HGMS, Flotation, True Heavy Liquids, Agglomeration | 1.5-8 | 2-4 | | 4 | 0.4 | 1.1 | | 95<br>90 | | 1.20<br>2.10 | 1420 [2]<br>1920 [4] | 0.26<br>0.38 | | 1.58<br>2.79 | 0.38<br>0.69 | Oil Designed Utility and Industrial Boilers<br>New Industrial Boilers and Heaters |
| IV Extensive Physical (15 Microns x 0) HGMS, THL, Flotation, Agglomeration | .2-2 | 16-2.1 | | 0.5 | 0.1 | 1.1 | | 95<br>90 | | 1.20<br>2.10 | 1850<br>2400 | 0.30<br>0.35 [5] | | 1.64<br>2.78 | 0.43<br>0.68 | Oil Designed Utility & Industrial Boilers<br>Gas Designed Utility & Industrial Boilers<br>Industrial Process Heaters/Boilers<br>New Industrial Heaters Boilers |
| V Physical + Chemical | .95-1.1 | .1-.6 | | 0.8 | 0.1 | 0.3 | | 80<br>70 | | 1.20<br>2.10 | 10,000 [6]<br>20,000 | 0.63<br>0.75 | | 2.37<br>4.22 | 1.17<br>2.20 | Gas Turbines & Diesel Engines<br>Home & Commercial Heating<br>New Capacity, Electric Utility |

FIGURE II

| APPLICATIONS/MARKETS | QUALITY<br>COMPETING<br>Range % S | % Ash | FUEL<br>Average % S | % Ash | PRICE<br>COMPETING<br>$/MMBTU<br>Range | FUEL<br>Delivered<br>Average | ESTIMATED PRICE OF CLEANED FUELS BEING DEVELOPED$/MMBTU<br>Range | Average | MARKET (MAXIMUM) OIL DISPLACEMENT<br>1985 | 1990 | 2000 | MARKET (MAXIMUM, GAS DISPLACEMENT<br>1985 | 1990 | 2000 | MARKE<br>INTR. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| oal Designed Electric Utility | - | - | - | - | $1.10-2.35[1] | $1.90 | | | - | - | - | - | - | - | |
| oal Designed Util ow using oil/gas | 0.7<br>3.5 | 0.01<br>0.5 | .75 | 0.1 | 4.28 - 4.92 | 4.70 | 1.43 - $2.57 | | 383 | 383 | 383 | 10 | 10 | 10 | 987 |
| il Designed Util Large Ind Blrs | 0.7<br>3.5 | 0.01<br>0.5 | .75 | 0.1 | 4.28 - 4.92 | 4.70 | 1.58 - 2.79 | | - | 1200 | 1200 | 0 | 0 | 0 | 987 |
| ew CLM Designed nd Boilers & Htrs | .7<br>3.5 | .01<br>.5 | .5 | .1 | 4.28 - 4.92 | 4.70 | 1.64 - 2.78 | | - | 353 | 625 | - | 737 | 1170 | 995 |
| as Designed Util Ind Blrs & Oil es Ind Heaters | 0 | 0 | 0 | 0 | 3.28 - 4.52 | 3.68 | 1.64 - 2.78 | | -[4] | 900 | 900 | - | 3000 | 3000 | 995 |
| as Turbines | 0 | 0 | 0 | 0 | 3.28 - 4.52 | 3.68 | | | - | - | 150 | - | - | - | |
| iesel Engines | 0.05<br>1.0 | trace | .2 | 0 | 7.12 - 7.58 | 7.36 | 2.37 - 4.22 | | [4] | - | 150 | - | - | - | 2005 |
| ew Home heating Conv Heating | 0.05<br>1.0 | trace | .2 | 0 | 7.12 - 7.59 | 7.36 | 2.37 - 4.22 | | | - | 130 | 960 | 370 | 3600 | 2005 |
| ew Utility Capacity | NSPS | | NSRS | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | |

) Coal Week, September 1982, Coal Week Fuel Pricing Trend

) EIA

) Steam, B&W, 39th Edition

4) Assumed savings in marine and locomotive applications only. Coal Fired cogeneration could increase this number.

FIGURE III

HS&T (Fuqua)
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CONTROL TECHNOLOGY & COAL PREPARATION

Question #3: It is possible that a meaningful proof-of-concept project for chemical coal cleaning could involve substantial sums of money. To what extent does the Fossil Energy Program anticipate such an occurrence?

Answer: The present DOE schedule calls for conceptual design work for a proof-of-concept chemical cleaning project to begin in late FY 1985, assuming successful operation of the bench scale system. This design would be used to provide an estimate of the cost of such a project, and would be the first credible estimate of the cost and complexity of such a project. Thus, at this time, we do not have a good estimate of the cost of a proof-of-concept project for chemical coal cleaning, nor do we have the data (based on bench scale operation) for projecting the value of such a project.

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CONTROL TECHNOLOGY & COAL PREPARATION

Question #4: What are the most promising techniques for combined nitrogen and sulfur oxide removal in coal burning facilities? When do you expect any of these technologies to become commercial? What are the advantages of these systems over normal scrubbers?

Answer: The most promising concepts for combined $NO_x/SO_x$ cleanup in the Fossil Energy R&D program are the Fluidized-Bed Copper Oxide Process, the Electron Beam/Lime Spray Dryer Process and the Electron Beam/Ammonia Injection Process.

Assuming the ongoing and planned proof-of-concept test and evaluation projects are successfully completed in a timely manner and funds are forthcoming from the private sector for support of full-scale demonstration(s), commercialization of these processes could be initiated in the 1990 time frame.

These advanced systems offer advantages over existing scrubbers in the following areas:

- $NO_x$ Removal - Existing scrubbers remove only negligible amounts of $NO_x$. The advanced systems are working toward attaining the capability for a minimum of 90% $NO_x$ removal. In order for existing scrubbers to attain the same $NO_x$ control capability, an additional process must be employed, such as selective catalytic reduction (SCR) of $NO_x$ to remove molecular nitrogen via reaction with ammonia.

- Costs - Projected cost advantages for the advanced systems as compared to a limestone scrubber with SCR for $NO_x$ control combination of equivalent performance ranges from 18-60% for capital costs and 33-58% for first-year annual revenue requirements.

- Wastes - All of the advanced systems offer advantages in waste handling and management as compared to scrubbers that produce a sludge. The copper oxide process is a regenerable one that can produce either an elemental sulfur or sulfuric acid by-product. The electron beam/ammonia process results in a by-product that may have potential use as a fertilizer. The electron beam/spray dryer process yields a dry, benign waste suitable for landfill disposal.

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## SURFACE COAL GASIFICATION

Question #1: Please explain the major features of the gasifier at Waltz Mill, Pennsylvania. What is the status of that facility? Could a useful program be developed to use that facility? Is the Gas Research Institute still interested in this gasification process?

Answer: The ash agglomerating, pressurized, fluidized-bed process development unit at Waltz Mill is a two-reactor system containing all units operations from coal crushing-drying through quench scrubbing of the coal gas. Downstream units, such as acid gas removal, shift methanation or power generation are not included as part of the system.

The 15-ton-per-day gasifier unit was originally designed as a two-vessel system. In the first reactor, a devolatilizer, coal was heated to remove volatiles and to produce char particles that were non-caking. These char particles were then gasified in a second reactor using air and steam to produce the raw product gas which was recirculated through the devolatilizer, heating, and fluidizing the char-coal bed.

During the development of the process, it was demonstrated that caking coals, highly reactive coals, and coals with low or high ash content could be successfully handled in a single-stage gasifier. The single stage oxygen blown reactor has become the optimum configuration for this gasification concept.

Also, located at the facility is a commercial-scale, semi-circular, cold flow reactor model. This commercial fluidized-bed system facility (CFSF) permits observation and study of the fluidized-bed through a plastic wall. This 10-foot diameter model provides a cost effective tool for investigating such factors as jet behavior, solids circulation, injector location, etc. The data is used for corroborating theoretical models with experimental data and for defining detailed component design.

Currently, studies are in progress that utilized the single stage reactor and the CFSF to study the relationships between key operational parameters and the mechanisms controlling ash agglomeration, fluidization phenomena, deposit formation and fines recycle. These studies are being continued in FY 1984 on a run-by-run basis that recognizes the current uncertain status of the contractor. This uncertainty exists as a result of negotiations currently in progress between the Westinghouse Corporation and a possible buyer of their Synfuels Division. Although the present contract expires on June 30, 1984, activities are in progress to extend it until August 1984. This extension will provide the opportunity for Westinghouse to complete the negotiations on the sale of their Synfuels Division. It is believed that with the completion of the activities supported by this contract the development of the gasifier technology will have matured to the stage that it is ready for transfer to industry. Since this technology will have been developed through the proof-of-concept stage by the end of FY 1984 no additional funds were requested for activities in FY 1985.

The facilities located at the Waltz Mill site are capable of being used in support of any general development effort in the area of coal gasification, gas cleanup, reactor modeling, combustion, etc.

Although the Gas Research Institute is still interested in this gasification process and its potential for commercial development, it is believed that their continued interest in any effort pursued at the site will directly depend upon the activities supported, the test scheduled, and the goals of the program.

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SURFACE COAL GASIFICATION

Question #2: What is the Department's evaluation of the need for an advanced surface coal gasification program at the Waltz Mill facility in Pennsylvania?

Answer: Development of the Westinghouse gasifier began in 1972 under the auspices of the Office of Coal Research (a DOE predecessor agency). In the 1975, a 15 ton-per-day process development unit was constructed at the Westinghouse Waltz Mill facility near Madison, Pennsylvania. Following more than 8,000 hours of operation of the gasifier at the design conditions the concept has been shown to be technically feasible, the development has achieved the proof-of-concept stage and the technology is ready for transfer to industry. It is believed that industry shares this opinion about the status of the gasifier development as it has been proposed in at least four commercial projects. These projects included a single gasifier retrofit to the SASOL complex in South Africa, a two gasifier/combustion turbine facility at Gulf States Nelson Station near West Lake, Louisiana, an electric power/methanol plant at Fall River, Massachusetts, (New England Energy Park), and the Keystone medium-Btu gas facility in Somerset County, Pennsylvania. Although these projects are no longer active, the decisions leading to their termination were not technically oriented or based upon a judgement about the maturity of the technology; but rather, the decisions to terminate were primarily economic.

The Department believes that the data base generated during the test runs performed to date supports the conclusion that the gasifier technology has been developed through the proof-of-concept stage, that the technical risks associated with scale-up are at the level acceptable to industry, that the data base is adequate to support such scaleup, and that there is strong evidence of industrial interest in the technology and its potential for commercialization when the economic environment becomes more favorable.

Accordingly, no funds have been requested to continue the Advanced Surface Coal Gasifier development program at the Waltz Mill Facility.

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SURFACE COAL GASIFICATION

Question #3: What is the status of the Great Plains Coal Gasification Project? Do you believe that this project is on schedule and within cost estimates? Please provide a breakdown of the $3 million which you request for managing the Great Plains Coal Gasification Project.

Answer: As of February 29, 1984 the actual overall percent of completion was 97.6%, or 0.9% less than planned. Construction was 94.8% complete as compared to 97.0% that was planned in 1981 and only 0.2% behind the revised 1983 construction plan. The actual cost performance as of February 29, 1984, is running just under 7% of the estimated cost. The small variance indicates that the project is on schedule and within cost estimates.

DOE's primary objective as monitor and loan guarantor, during the design and construction phase of the project, is the control and proper release of federal funds. Monitoring of the financial and technical status of the project is required to assure that guaranteed funds are provided only when warranted and the government's actions are in the best interest of the public.

The government's contingent liability for this venture will last well into the plant's operating period, since payback of the loan is a long-term process, possibly lasting up to twenty years. Therefore, during this extended period, the government must periodically evaluate its financial obligation and involvement in the project. These milestones which must be met include achievement of:

- o steady state operations with reasonable yields,
- o interim levels of capability build-up,
- o design capacity or rated capability,
- o specified level of plant operability (on-stream factor), and,
- o specified component/subsystem reliability/replacement factors.

Various types of programmatic information will require attentive review during the design, construction, and operational phases of the project. The overall project condition will be evaluated by comparing current project status against established baselines of technology, cost, schedule, environment, safety, and socioeconomic effects or impacts.

The DOE Fossil Energy Office of Oil, Gas, Shale and Coal Liquids is the DOE Program Manager for the Great Plains Gasification Project (GPGP) Loan Guarantee. DOE's Chicago Operations Office serves for the DOE Program Manager as the primary project monitoring activity and provides for the integrated technical and business assessment of the project. DOE's Morgantown Energy Technology Center and the Grand Forks Project Office have been assigned project monitoring, data management and technical support roles to assist the program and project managers in carrying out their responsibilities.

DOE funding for GPGP monitoring activities in 1984 is:

| | |
|---|---|
| HQ Program Office | $ 1,369,000 |
| Chicago Operations Office | 881,000 |
| Morgantown Energy Technology Center | 750,000 |
| | $ 3,000,000 |

These monitoring funds are being used for contract studies on the following:

- o Validation of capital costs, including labor, materials, components, and instrumentation.
- o Development of data on operational, maintenance and raw material costs.
- o Development of schedule data associated with the planning, design/procurement, construction, initial operation and continual operation of the facility.
- o Development of project planning and control, licensing, permitting, regulatory compliance, liability risk and financing term information.
- o Validation of data on tax treatment, technology transfer, and product pricing.
- o Development of data on product quality, product slate capabilities and markets, and by-product utilization.

- Validation of approaches to ecology monitoring, pollutant fate and reclamation; mitgation and control approaches; environmental compliance including air quality, water quality, and solid waste control; establishment of data on public and occupational health and safety including medical surveillance, industrial hygiene, epidemiology and toxicology.

- Validation of socioeconomic impact predictions and infrastructure requirements; impact mitigation process, and requirements for replicating that process.

This information will be used within DOE to assess project performance, identify future high payoff R&D and to support industry and the U.S. Synthetic Fuels Corporation (SFC).

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## OIL SHALE

Question #1: In your budget request, you indicate that Eastern oil shales are currently receiving increased industrial interest. How is this development reflected in your proposed oil shale program for FY 1985? Do you believe the program is well-balanced to reflect the potential of both Eastern as well as Western oil shales?

Answer: The Oil Shale Program is being redesigned as directed by Congress. The program will reflect inputs from industry and an in-depth evaluation of the program. The redesigned program is currently being reviewed by Fossil Energy Headuarters. The proposed program for FY 1985 is well balanced and supports those efforts that are principally generic and fundamental research. These efforts should provide the basic understanding necessary for industry to design more efficient, economic and environmentally benign processes.

The redesigned oil shale program addresses both Eastern and Western shale recognizing the difference in geochemical make-up, but also that much of the Western shale research has application to Eastern shales as well. The $12,000,000 funding level allows DOE to conduct a broad based program in both Eastern and Western shales addressing:

- Resource Characterization - In-depth analysis of geochemical, geophysical, thermophysical, and thermodynamic properties.

- Fundamental Research - Determining the fate of highly characterized shale in varying process conditions, i.e., how the process conditions affect product yield and quality, and speciation and concentration of pollutants in the air, water and solid waste streams.

- Advanced Research - Novel concepts for addressing the oil shale conversion and environmental impact mitigation problems.

- Environmental Studies - The development of methodologies to quantify the effect of siting on the environment to include fundamental research in the kinetics, chemistry and mechanisms of air and water clean-up technologies. A broad based program in solid waste management to identify and quantify the parameters affecting the chemical and physical stability of spent shale piles is also planned. Environmental constraints currently being studied include particulate and $SO_2$ emissions from mining and handling as well as aqueous waste streams from retorted shale. All pose potential major environmental problems to siting future oil shale plants.

The Department will continue to develop and refine its Oil Shale R&D program in close consultation with industry, Congress and other interested parties. Comments will be used in completing the planning process.

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UNCONVENTIONAL GAS RECOVERY

Question #1: Please explain the separation of responsibilities between the Gas Research Institute and DOE in unconventional gas recovery.

Answer: The Gas Research Institute supports a broad-based R&D program in unconventional gas resources. GRI's areas of interest include the Tight Gas Sands (blanket and lenticular reservoirs), Eastern Devonian Shales, Methane from Coal Seams, Co-Production of Gas and Water from depleted reservoirs, and Abiogenic sources of methane.

DOE concentrates its research efforts in the establishment of a technology base to support industry development of advanced technologies and strategies to increase the economic attractiveness and to help assure adequate future gas supplies from the unconventional gas resource. Subprograms supported at DOE include the Western Gas Sands (lenticular reservoirs), Eastern Devonian Shales, Gas Hydrates, and Deep Source Gas.

The DOE and GRI programs are complementary in nature and in most cases allow for a comprehensive research coverage of a resource. A cooperative agreement for unconventional gas research exists between the two parties.

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UNCONVENTIONAL GAS RECOVERY

Question #2: Why does the Department have no program in coal-bed methane recovery? Is it commercial? Is additional R&D necessary?

Answer: The DOE program in coal-bed methane recovery has been brought to an orderly close. The former DOE program supported several experiments that demonstrated the production and utilization of methane produced from coalbeds, establishing a technology base to support further private sector development.

At the present time commerical quantities of coalbed methane gas are being produced in the Warrior Basin of Alabama. In addition, there are scattered commercial wells throughout various coal basins particularly in the Western United States.

Although coal-bed methane recovery is a commercial technology, there are nonetheless areas where additional R&D activities can be beneficial. These areas include further study of coalbed properties relative to depth and their response to different stimulation techniques; increased predictive production performance through the collection of reservoir property data, and further development and refinement of reservoir models. These R&D areas are evolutionary in nature and should be a private sector responsibility with assistance from the Gas Research Institute (GRI).

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UNCONVENTIONAL GAS RECOVERY

Question #3: In your budget request for FY 1985, you indicate that the Department has submitted a deferral request for all activities relating to geopressured methane in the DOE fossil program. However, do you believe that it might be reasonable to consolidate all of the Department's unconventional gas programs, including the geopressured program, within one central office? If not, why not?

Answer: At the present time, all unconventional gas research programs, with the exception of geopressured methane activities, are under the Assistant Secretary for Fossil Energy management. However, since the Geothermal/Geopressured program has the multiple objectives of thermal and mechanical recovery, and co-production of gas, the Department believes it is more beneficial to have the management of these programs reside in the Office of the Assistant Secretary for Conservation and Renewable Energy (CE). CE intends to determine the gas recovery potential in the pursuit of their programs. As agreed upon through discussions early in the fiscal year, Fossil Energy will serve in a technical advisory capacity to CE on gas recovery matters.

# FISCAL YEAR 1985
# DEPARTMENT OF ENERGY
# AUTHORIZATION

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## THURSDAY, MARCH 8, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Development Applications,
*Washington, DC.*

The subcommittee met, pursuant to call, at 2 p.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the subcommittee) presiding.

Mr. **Fuqua**. We begin the last of the Department of Energy's fossil energy research and development hearings. We have heard from the congressional, departmental, and industrial witnesses, and we will conclude today with witnesses from the private sector.

Our first group will address the issues involving the gas industry. Their concerns run from coal use in fuel cells and gasification programs to the development of hard to produce and exotic gas resources, and the more efficient use of gas and equipment being developed in conjunction with the Conservation Division of the Department of Energy.

The second panel is mainly concerned with reduced funding for ongoing programs in MHD, liquefaction of coal and the development of eastern oil shales.

We are pleased to have our group here today. Our first panel will be Dr. Bernard Lee, president of the Institute of Gas Technology—we are happy to have you back again; David Webb, senior vice president for Gas Research Institute—Dave, we are pleased to welcome you; and Mr. William Morse, director of research for Columbia Gas System.

Also, without objection, Mr. Winn's statement will be made part of the record following my opening statement.

Also, without objection, permission will be granted to take photographs and recordings, et cetera, during the course of the hearing.

[The opening statement of Mr. Winn follows:]

STATEMENT BY THE HONORABLE LARRY WINN, JR.
ENERGY DEVELOPMENT AND APPLICATIONS SUBCOMMITTEE
HEARING ON
FY 1985 DOE AUTHORIZATION FOR FOSSIL R&D PROGRAMS
MARCH 8, 1984

THANK YOU, MR. CHAIRMAN. I WANT TO WELCOME OUR WITNESSES TODAY, SEVERAL OF WHOM HAVE VISITED WITH US IN THE PAST. THE SUBJECT MATTER IS THE FOSSIL ENERGY RESEARCH AND DEVELOPMENT PROGRAM FUNDING REQUESTED BY THE U.S. DEPARTMENT OF ENERGY FOR FY 1985 AUTHORIZATION. THE PROGRAMS TO BE DISCUSSED TODAY INCLUDE GASIFICATION OF COAL, LIQUEFACTION OF COAL, THE MHD PROCESS, AND EASTERN SHALE, TO NAME SEVERAL. THIS HEARING PROMISES TO BE VERY INFORMATIVE.

AS I HAVE STATED AT THE TWO EARLIER FOSSIL HEARINGS THIS YEAR, THE BUDGET PROPOSED BY DOE APPEARS TO BE QUITE ADEQUATE, EFFECTIVELY COVERING THE PROGRAM SCOPE. IT IS NECESSARY TO REMIND OURSELVES OCCASIONALLY THAT WE CONTINUE TO OPERATE IN A RELATIVELY NEW PHILOSOPHY, THAT THE LIMITED FUNDS AVAILABLE WILL BE DEVOTED TO BASIC, FUNDAMENTAL RESEARCH, RATHER THAN PILOT AND DEMONSTRATION PLANT CONSTRUCTION AND OPERATION. IT IS UNFORTUNATE THAT COAL IS CHARACTERIZED AS A MATURE, DEFINED RESOURCE. NATURALLY WE HAVE BURNED COAL AS A FUEL FOR CENTURIES IN THIS COUNTRY. HOWEVER, NEITHER THE DIRECT COMBUSTION NOR CONVERSION PROCESSES ARE PREDICTIVE PROCESSES. IT IS TRUE THAT WE HAVE AMASSED A LARGE AMOUNT OF EMPIRICAL DATA, BUT THE SAD TRUTH REMAINS THAT WE CANNOT PREDICT WITH ACCURACY HOW ANY COAL WILL BEHAVE IN ANY PROCESS UNTIL WE HAVE RUN THAT COAL IN THAT PROCESS.

IT IS QUITE EVIDENT THAT THIS COMMITTEE WELCOMES DISCOVERY AND INNOVATION AMONG THE PROGRAMS WHICH IT HAS ALWAYS SUPPORTED. FOSSIL ENERGY IS NO EXCEPTION. THEREFORE, IF AT ANY TIME DOE HAS MADE A TECHNICAL BREAKTHROUGH OR HAS, THROUGH RE-EVALUATION, CHANGED PROGRAM PRIORITIES, WE WILL BE GLAD TO WORK WITH DOE TO RESTRUCTURE THE FOSSIL ENERGY PROGRAM WITHIN THE REQUESTED FUNDING LEVEL. OTHERWISE, PROGRAM CONTINUITY AND VIGOR WOULD BE COMPROMISED.

MR. CHAIRMAN, THANK YOU FOR THIS OPPORTUNITY TO MAKE A FEW REMARKS ON TODAY'S HEARING. I LOOK FORWARD TO HEARING FROM OUR WITNESSES.

Mr. Fuqua. If you have a prepared statement, we will, without objection, make those in their entirety part of the record. If you wish to summarize, that would be very accommodating.

## STATEMENTS OF BERNARD S. LEE, PRESIDENT, INSTITUTE OF GAS TECHNOLOGY; DAVID O. WEBB, SENIOR VICE PRESIDENT, POLICY AND REGULATORY AFFAIRS, GAS RESEARCH INSTITUTE; AND WILLIAM MORSE, DIRECTOR OF RESEARCH, COLUMBIA GAS SYSTEM, ACCOMPANIED BY MICHAEL BALY III, VICE PRESIDENT, AMERICAN GAS ASSOCIATION

Mr. Lee. Thank you, Mr. Chairman.

I feel that America urgently needs a mature energy policy to provide long-term stability and security in energy. However, in today's fast-paced microchip world in which innovations and obsolescence are measured in years rather than decades, we tend to apply the same criteria of quick turnovers to all national needs.

That would be a mistake in the energy field. Energy policies must be established with long-term stability and security as top priority, paying special attention to the available and accessible energy sources, both in the United States and in specific geographic locations in the world.

From a world perspective, we must focus our attention on the steady growth in population, especially in developing countries. Nations that have been existing on extremely low per capita energy consumption represent sources of explosive energy demand as they respond to internal pressures for even a modest improvement in living standards. It is pointless to expect those nations that have substantial energy resources and large populations to become significant energy exporters because their rising domestic demands will soon require all their supplies. For nations without substantial energy resources, growing populations will exert enormous pressure on the distribution of available world energy resources.

From a U.S. perspective, I am deeply troubled by the complacency with which we view energy. The issues on the public's mind are defense, toxic waste, entitlements, education, world peace—but not energy. Such misplaced priority is myopic. We know that fossil fuels will have to provide the bulk of our energy needs well into the 21st century, until renewable resources and, possibly, fusion energy can assume major roles. But Federal support for fossil fuel R&D is inadequate in view of the steadily declining oil and gas reserves in the United States. In this atmosphere of complacency, conservation is also receiving less support, even though it has been amply demonstrated that conservation is capable of sharply reducing energy requirements and costs to the consumers.

A mature energy policy must have three elements. First, there must be balance—balance between providing adequate energy supply and conserving energy resources through high efficiency in utilization; also, balance within the energy supply sources between nuclear and fossil. In the past, we oversold the nuclear option. We put disproportionate emphasis on nuclear R&D while we undersold and neglected fossil fuel and renewable energy resources to the point where our largest indigenous energy resource is grossly underutilized. This unbalanced energy mix, this gap between what we have and what we use, must be eliminated before we can expect long-term stability.

Second, a mature energy policy must preserve the environment. Acid rain has become a national, and international, issue. The fundamental way to solve acid rain is to, first, remove all the sulfur from the coal by gasification and gas cleanup, and then burn this clean fuel gas in advanced efficient combustion equipment.

Cogeneration, combined cycle or fuel cell power generation, substitute natural gas, chemical synthesis are all examples of combining coal gasification with efficient utilization. Stop-gap measures that don't solve the root causes of acid rain cannot succeed. We must eliminate the gap between our desire for environmental preservation and our willingness to invest in appropriate new technologies.

Third, a mature energy policy must provide continuity and sustained support for technology development to ensure the smooth flow of technology from the laboratory to commercial use. Although we fund substantial energy R&D, we lag behind many other countries which have adopted a policy of continuing, consistent and adequate funding of R&D to develop their indigenous energy resources.

The International Energy Agency's recent review of the 1982 national programs of R&D in 19 IEA countries showed the United States ninth in the ratio of government expenditures on energy R&D to gross domestic product, and 10th in the ratio of energy R&D to total primary energy demand. Excluding nuclear R&D, the United States falls to 11th and 16th, respectively.

The current Federal R&D funding supports long-range, high-risk technologies. That alone is not enough. We need more than just basic research that enriches the scientific literature. Energy research is principally applied research; we must support the whole chain of development, from basic research to commercial applications. Yet, the current DOE program limits technology development support only through the proof-of-concept stage, leaving the key process development and commercial demonstration stages to the private sector. But there is no way that the private sector can do this, since these stages are the highest risk and most costly links in the overall development chain, and require a timespan of 10 or more years.

While this gap exists and while we wait for action, world energy supplies will very likely experience disruptions in less than 10 years, and we, as a nation, will be caught unprepared. That risk is far greater and will cost the Nation far more than getting ourselves prepared through the implementation of a mature energy policy that eliminates this gap in technology development.

For fiscal year 1985, therefore, I support the gas industry recommendations for $150 million in DOE appropriations for gas-related R&D, comprising the major categories of: $54 million for gasification; $31 million for unconventional and geopressured resources; $20 million for biomass; $20 million for fuel cells; $22 million for conservation; $3 million for LNG safety.

IGT highlights the following recommended programs:

In coal gasification, $6 million to use an existing process research unit to extend the U-GAS ash agglomeration gasification technique to high pressure on all types of U.S. coals in order to bring this advanced technology closer to commercial application. The work at IGT has shown that the ash agglomerating fluidized bed can achieve excellent conversion efficiency with many coals, even low-quality, high-ash, high-sulfur, and highly caking coals. Extending the existing data base to 500 psi would maximize overall efficiencies for combined cycle power generation and for the production of methanol, substitute natural gas, and chemicals. We must expand our data base to include basic process understanding of the gasification kinetics, trace component formation, and ash characteristics as these parameters are influenced by pressures in the 500-psi range.

IGT will bring significant contributions to this project by providing the use of its own 500-psi, 8-inch-diameter process research unit and many other related equipment and facilities, and anticipates substantial funding by the Gas Research Institute with DOE to carry out this program.

Also in coal gasification, $10 million to develop a broad technology base including research on fluidization, gasification mechanisms, ash chemistry, gas cleanup, and transfer of R&D results.

In oil shale gasification, $1 million to use existing facilities for converting spent shale residues to nonleachable agglomerates for disposal.

In unconventional gas resources, $1 million for expanded measurements of rock properties in Devonian shale; $1.5 million to expand core analyses from the multiwell experiment in western tight sands and to measure two-phase flow in rock pores; and $1 million for research on relaxation channels in coal seams to stimulate gas flow.

In geopressured methane, $5 million for definitive data collection from existing design wells; plus $1 million for expanded measurements of relative permeability and critical gas saturation.

In thermochemical conversion of biomass, $1 million to expand the data base of the RENUGAS process in an existing pressurized process research unit.

In biological conversion of biomass, $1 million to thoroughly study the first known inoculum which can gasify untreated woody biomass, and $1 million to establish digester performance of giant brown kelp in a process research unit.

In converting wastes to fuels, $1 million for developing, on a process research unit scale, the two-phase biological digestion of municipal sewage sludge which has produced twice as much methane per unit of waste than heretofore possible; and $0.5 million for conducting tests on an existing landfill to produce gaseous fuels through a two-phase leachate recycle process.

In fuel cells, $6 million to use existing facilities to expand the technology base of molten carbonate fuel cells through components evaluation, prototype endurance, contaminant effects, and electrolyte preparation.

In residential conservation, $1 million to develop an indoor air quality model; $2 million for an advanced gas/solar desiccant system for residential heating and cooling; and $1 million for advanced heat pump development based on the Hyperabsorption cycle.

In industrial conservation, $3 million to develop thermochemical recuperation of high-temperature waste heat and $2 million to develop an advanced cyclonic melter.

In hydrogen, $1 million for research and systems analysis of three promising hybrid cycles for thermochemical hydrogen production.

Finally, in addition to the gas industry recommendations, IGT recommends $4 million for the intensified development of thermal energy storage using composite molten-salt, phase-change materials.

Thank you for this opportunity to present my views. I will be happy to answer any questions.

[The prepared statement of Mr. Lee follows:]

Statement by Bernard S. Lee, President
Institute of Gas Technology
Before the House Committee on Science and Technology
Subcommittee on Energy Development and Applications
Hearing on FY1985 Authorization for the Department of Energy's
Fossil Energy Research and Development Program

March 8, 1984

Mr. Chairman and Members of the Subcommittee:

My name is Bernard S. Lee. I am President of IGT, a not-for-profit energy R&D organization in Chicago.

To meet its long-range energy needs and to preserve its environment, as well as that of its neighbors, America needs clean fuels which can be utilized at high efficiencies. We urgently need a mature energy policy that directs a balanced and sustained program to develop appropriate technologies to meet these needs. However, caught up in today's fast-paced microchip world in which innovations and obsolescence are measured in years rather than decades, we tend to apply the same criteria of quick turnovers to all national needs. That would be a mistake in the energy field. Energy policies must be established with long-term stability and security as top priority, paying special attention to the available and accessible energy sources, both in the U.S. and in specific geographic locations in the world.

From a world perspective, we should focus our attention on the steady growth in population, especially in developing countries. Nations that historically have existed on extremely low per capita energy consumption represent sources of explosive energy demand as they respond to internal pressures for even a modest improvement in living standards. It is pointless to expect those nations that have substantial energy resources and large populations to become significant energy exporters because their rising domestic demands will soon require all their supplies. For nations without substantial energy resources, growing populations will exert enormous pressure on the distribution of available world energy resources.

In the past, we oversold the nuclear option. Mesmerized by the promise of inexhaustible energy supply, we have disproportionately emphasized that option in terms of R&D expenditure in anticipation of unrealistically rapid deployment of nuclear installations. On the other hand, we undersold and neglected fossil fuel and renewable energy resources to the point where our largest indigenous energy resource is grossly under-utilized. The result is an unbalanced energy mix that will not lead to long-term stability.

We must have a maturity of energy policy for the United States which ensures the smooth flow of technology from the laboratory to commercial use and which realistically addresses future energy options. Although we fund large amounts of energy R&D, we fall behind many other countries which have adopted a policy of continuing, consistent and adequate funding of R&D to develop their indigenous energy resources. The International Energy Agency recently published a review of the 1982 national programs of R&D in the IEA countries. It is interesting to note that the United States is 9th in the ratio of 1982 government expenditures on energy R&D to gross domestic product, and 10th in the ratio of energy R&D to total primary energy demand. If nuclear R&D is excluded, the United States falls to 11th and 16th, respectively, of the 19 countries in the review.

I am deeply concerned by the complacency into which we have been lulled by the current energy situation. The issues on the public's mind are defense, toxic waste, entitlements, education, world peace, but not energy. Such misplaced priority is myopic. We know that fossil fuels will have to provide the bulk of our energy needs well into the 21st century, until renewable resources and, possibly, fusion energy can assume major roles. But, if we look at conventional oil and gas, warning signals are already evident. Domestic oil reserves peaked in the 1950's and have been declining ever since. The U.S. Geological Survey has warned that world oil resources may be even smaller than conservative estimates. Let us not forget that we still import large quantities of oil, and most energy analysts project even higher imports in future years. This has obvious implications for national policy on security and economic well-being.

The natural gas situation is similar. Proved reserves peaked in the mid-1960's and have dropped sharply since that time. Since 1967, yearly additions to reserves have been less than production for every year except 1981. Although indigenous natural gas supply is somewhat more favorable than oil supply, eventually we must turn to imports, development of unconventional gas sources, and synthetic gas to supplement natural gas supplies.

In this atmosphere of complacency, less support is also being given to efficient utilization technologies and applications, even though it has been amply demonstrated that conservation is capable of sharply reducing energy requirements and costs to the energy consumer. Renewable energy sources, too, are receiving less attention although these must become part of our future energy supplies.

A mature energy policy must preserve the environment. The acid rain issue is one of national and international concern. The expanded use of coal, our most abundant resource, must be anchored upon a technically sound and efficient base that complies with present and projected environmental regulations. The fundamental way to solve acid rain is first to totally remove sulfur and nitrogen from the coal by gasification and downstream processing and then to burn this clean fuel gas in advanced efficient combustion equipment. The more efficient the fuel utilization step, the less resource will be needed and the less pollutants emitted. Examples of coal gasification plus efficient utilization include cogeneration, combined cycle or fuel-cell power generation, industrial fuel gas, substitute natural gas, and chemical synthesis. Stop-gap measures to provide marginal improvements to alleviate immediate public pressures do not eliminate the root causes of acid rain, and therefore cannot succeed.

The current Federal R&D funding supports long-range, high-risk technologies. That alone is not enough. We need more than just basic research that enriches the scientific literature. Energy research is principally applied research; we must support the whole chain of development, from basic research to commercial applications. Yet, the current Department of Energy program limits technology development support only through the proof-of-concept step; the key process development and commercial demonstration steps are being left to private industry. However, these steps are the most costly and high-risk links in the chain. They require a time span of 10 or more years. In today's economic environment the private sector cannot undertake these risks. Unfortunately, the distinct possibility exists that world energy supplies will be interrupted at much shorter intervals than 10 years, and we as a nation will be caught unprepared. That risk is greater and will cost the nation more than the risk and cost of getting ourselves prepared through the implementation of a mature energy policy.

FY 85, I support the gas industry recommendations for $150 million in DOE appropriations for gas-related R&D, plus $4 million for thermal energy storage. Specific recommendations for programs are summarized in Attachment 1 and detailed in Attachment 2 of this testimony. I will highlight a few areas below.

## Gasification

Of the $54 million gasification program recommended by the gas industry, in coal gasification IGT emphasizes two categories. Toward bringing advanced technology closer to commercial application, IGT recommends $6 million for a test program using the currently operating process research unit to extend the U-GAS ash agglomerating fluidized bed gasification technique to 500 psi on all types of U.S. coals in order to bring this advanced technology closer to commercial application. The work at IGT has shown that the ash agglomerating fluidized bed can achieve excellent conversion efficiency with many coals, even low-quality, high-ash, high-sulfur, and highly-caking coals. Extending the existing data base to 500 psi would maximize overall efficiencies for combined cycle power generation and for the production of methanol, substitute natural gas, and chemicals. We must expand our data base to include basic process understanding of the gasification kinetics, trace component formation, and ash characteristics as these are influenced by pressures in the 500 psi range. IGT will bring significant contributions to this project by providing the use of its own 500-psi 8-inch-diameter Process Research Unit and many other related equipment and facilities, and anticipates substantial funding by the Gas Research Institute with DOE to carry out this program.

Toward developing a broad technology base, $10 million is recommended comprising: $1 million on the investigation of the attrition and entrainment from fluidized-bed gasifiers in an existing Advanced Multi-purpose Research Reactor (AMRR); $0.5 million to study coal reaction mechanism using the ion impact technique; $0.5 million on gasification mechanism of sulfur, nitrogen and trace elements through using the isotopic labeling technique; $1 million on the behavior of coal ash during gasification; $0.5 million on determining the multi-component thermophysical properties of gasifier effluent streams; $1.5 million for testing composite sorbents in a bench-scale research unit for the removal of sulfides and halides; $1 million for bioprocessing of raw gasifier effluent to remove sulfur and produce methane; $2 million to determine the gasification characteristics of wet carbonized coals; $1 million for liquid-sealed lockhopper system; $1 million for compilation, evaluation, and correlation of coal gasification data useful to design engineers and scientists.

All current retorting technologies for oil shale discard potentially leachable residues and/or unretorted shale fines. IGT recommends $1 million to operate existing facilities for gasifying and agglomerating shale residues to recover the carbon value and to produce environmentally benign, non-leachable spent shale agglomerates for disposal.

## Unconventional and Geopressured Resources

This $31 million program supported by the gas industry covers research in tight sands, Devonian shale, geopressured methane, deep source methane, gas hydrates, and methane from coal seams, all of which require intensive development before these tremendous energy resources can be utilized efficiently. In particular, we highlight a $1 million recommendation to expand the use of an existing computer-operated rock analysis laboratory (CORAL) to accurately determine the rock permeability and porosity properties of Devonian shale.

In support of the multi-well experiment in western tight sands, we recommend $1.5 million to analyze MWX cores and to augment core analysis in the Experimental Tight Rock Analysis (EXTRA) equipment to study two-phase flow in rock pores in order to allow comparison of actual production data with evolving computer models.

A $1 million program is recommended to use existing equipment to study the effect of relaxation channels in coal seams on permeability and compressive stress for several gassy coals.

In geopressured methane, $5 million is recommended for the collection of co-production data from existing design wells, and $1 million for accurately measuring compressibility, critical gas concentration, and relative permeability of brine to gas by upgrading laboratory equipment so that these data can be correlated with field data to permit predicting gas production from both geopressured and hydropressured wells.

Under advanced unconventional gas, $0.5 million is recommended for methane hydrates study to simulate its formation under natural conditions and to measure gas diffusion rate through the sediments.

Biomass

The $20 million program supported by the gas industry includes R&D in the thermochemical and biological conversion of biomass, the conversion of wastes, the growth and harvest of biomass and the support of regional programs. In biomass conversion, we highlight a $1 million recommendation to expand the data base of the RENUGAS process in an existing pressurized process research unit that converts biomass thermochemically to medium-Btu gas fuel or to synthesis gas, and $0.75 million to investigate the gasification behavior of biomass structural components and the catalytic reforming of heavy oils and tars produced in a biomass gasifier. Under biological conversion, we recommend $1 million to study the first known inoculum which can gasify untreated woody biomass to produce useful fuel gas, $1 million to establish digester performance of giant brown kelp in a process research unit, and $1 million to study microalgae and organisms for the production of fuels and chemicals.

In waste conversion, we recommend $1 million to construct and operate an on-site process research unit for the two-phase digestion of municipal sewage using a novel up-flow solids digester which has produced twice as much methane per unit of waste than heretofore possible, and $0.5 million to conduct tests on an existing landfill for producing gaseous fuels through a two-phase leachate recycle process.

Fuel Cells

The $20 million fuel cell progam supported by the gas industry includes first-generation phosphoric acid fuel cells, second-generation molten carbonate fuel cells, and other advanced concepts. Of these, the molten carbonate fuel cell has potentially the best combination of performance, efficiency, and cost to capture major portions of power generation and co-generation applications. This system lends itself to the use of coal through gasification or natural gas through internal reforming within the fuel cell.

A multi-year program with FY85 funding of $6 million is recommended to expand the technology base of the molten carbonate system by using existing facilities for evaluating components, testing prototype endurance, measuring effect of contaminants, and preparing electrolytes is a controlled environment.

## Conservation

The $22 million program recommended by the gas industry covers building and community systems, industrial, transportation and hydrogen. We highlight under building and community systems a $1 million recommendation to develop an indoor air quality model based on existing comprehensive air infiltration model that would allow the evaluation of various alternative strategies for indoor air quality control. A $2 million program is recommended to develop an advanced desiccant system for residential environmental control with coefficient of performance up to 50 % higher than conventional air conditioning systems. $1 million is recommended to initiate a program to test and evaluate an advanced Hyperabsorption cycle heat pump. $0.5 million is recommended to develop an advanced analytical model for high-efficiency adiabatic diesel engines.

Under industrial conservation, we recommend several promising new approaches. The first is thermochemical recuperation of high-temperature heat from industrial furnaces into both combustion air and fuel, for which a $3 million program is recommended to develop a sub-scale facility to evaluate design parameters, conversion rates, and materials compatibility. The second is a $2 million program to develop a high-efficiency cyclonic melter which has broad applications in glass manufacture and mineral ore processing. In addition, $1 million program is recommended for development of an advanced combustor concept for industiral applications in which the heat exchange surface is located directly in the combustion zone, and $0.5 million is recommended to develop an advanced firetube melter for aluminum reovery.

Hydrogen research through thermochemical or thermoelectrochemical cycles using nuclear fusion, fission or solar energy as a high temperature heat source is recommended in a $3 million program, of which $1 million is assigned to evaluating three promising hybrid hydrogen cycles based on copper, zinc, and cadmium chemistry.

## Thermal and Mechanical Energy Storage

Energy stored as heat at elevated temperature, or thermal energy storage (TES), can later be used for on-site commercial or industrial applications. One thermochemical method to accomplish TES is the use of melted salts or salt mixtures.

IGT recommends, within the Thermal and Mechanical Energy Storage category, $4 million for the intensified development of thermal energy storage using composite molten-salt phase-change materials.

Thank you for the opportunity to present my views. I will be happy to answer your questions.

### ATTACHMENT 1
### TO STATEMENT BY BERNARD S. LEE
### March 8, 1984

For FY'85, IGT specifically recommends:

- $6 million for a test program using the pressurized U-GAS ash agglomeration process research unit
- $10 million for coal gasification technology base research
- $1 million for converting spent shale residues to non-leachable agglomerates for disposal
- $1 million for expanded Devonian shale rock property measurements
- $1.5 million to continue augmented core analyses of Western tight sands to study two-phase flow in rock pores
- $1 million for research on relaxation channels in coal seams to stimulate gas flow
- $5 million for the collection of co-production data from geopressured design wells
- $1 million for expanded measurements of relative permeabilities and critical gas saturation in geopressured formations
- $0.5 million for study of methane hydrates formation and behavior under natural conditions
- $1 million to expand the data base of the RENUGAS process
- $0.25 million to investigate the gasification behavior of biomass structural components
- $0.5 million for research on the catalytic reforming of biomass gasifier liquid products
- $1 million for biological gasification of woody biomass without pretreatment
- $1 million for a process research unit to convert giant brown kelp to fuels
- $0.75 million to study microalgae and microorganisms for producing fuels from biomass
- $1 million for the two-phase biological digestion of municipal sewage sludge
- $0.5 million for LANFILGAS process development
- $6 million for technology base expansion of the molten carbonate fuel cell
- $1 million to develop an indoor air quality model
- $2 million for an advanced gas/solar desiccant system for residential heating and cooling
- $1 million for the development of Hyperabsorption heat pump cycle
- $0.5 million for diesel engine performance improvement
- $3 million for development of a novel thermochemical recuperative system
- $2 million for development of an advanced cyclonic melter
- $1 million for a novel surface combustor development
- $0.5 million for an advanced firetube aluminum melter development
- $1 million for hybrid hydrogen cycles evaluation
- $4 million for thermal energy storage using composite molten-salt phase-change materials

## GASIFICATION

### Coal

IGT recommends $6 million for a test program using the currently operating process research unit to extend the U-GAS ash agglomerating fluidized bed gasification technique to 500 psi on all types of U.S. coals in order to bring this advanced technology closer to commercial application. The work at IGT has shown that the ash agglomerating fluidized bed can achieve excellent conversion efficiency with many coals, even low-quality, high-ash, high-sulfur, and highly-caking coals. Extending the existing data base to 500 psi would maximize overall efficiencies for combined cycle power generation and for the production of methanol, substitute natural gas, and chemicals. We must expand our data base to include basic process understanding of the gasification kinetics, trace component formation, and ash characteristics as these are influenced by pressures in the 500 psi range. IGT will bring significant contributions to this project by providing the use of its own 500-psi 8-inch-diameter Process Research Unit and many other related equipment and facilities and anticipates substantial funding by the Gas Research Institute with DOE to carry out this program.

IGT also recommends $10 million to carry out technology base research comprising: $1 million on the investigation of the attrition and entrainment from fluidized-bed gasifiers in an existing Advanced Multi-purpose Research Reactor (AMRR); $0.5 million to study coal reaction mechanism using the ion impact technique; $0.5 million on gasification mechanism of sulfur, nitrogen, and trace elements through using the isotopic labeling technique; $1 million on the behavior of coal ash during gasification; $0.5 million on determining the multi-component thermophysical properties of gasifier effluent streams; $1.5 million for testing composite sorbents in a bench-scale research unit for the removal of sulfides and halides; $1 million for bioprocessing of raw gasifier effluent to remove sulfur and produce methane; $2 million to determine the gasification characteristics of wet carbonized coals; $1 million for liquid-sealed lockhopper system; $1 million for compilation, evaluation, and correlation of coal gasification data useful to design engineers and scientists.

### Shale

All current retorting technologies for oil shale discard unretorted shale fines and potentially leachable residues that represent environmental problems. These materials contain carbon which amounts to as much as 50% of the total energy available in the shale as mined. IGT recommends $1 million to operate existing gasification equipment to develop the ash agglomerating fluidized-bed technique for gasifying and recovering the carbon in shale discards and producing environmentally benign, non-leachable spent shale agglomerates for disposal.

## UNCONVENTIONAL AND GEOPRESSURED RESOURCES

- Accurate determination of the Devonian shale rock properties is critical to the capability of predicting gas production from this resource. IGT's computer operated rock analysis laboratory (CORAL) provides both permeability and porosity measurements representative of in-situ conditions. IGT recommends $1 million to expand the CORAL facility and the Devonian shale property measurements.

- The current work on the western tight sands multi-well experiment (MWX) core sand provided the first basis for comparing post-hydraulic fracture production with predictions based on reservoir rock properties. IGT recommends $1.5 million to continue analysis of the MWX cores in CORAL and to augment core analyses in the experimental tight rock analysis (EXTRA) equipment used to study two-phase flow in rock pores so that existing predictive computer models using the measured physical property data could be compared with actual production data.

- IGT's continuing research on coal seam methane production has led to the first understanding of how hydraulic fracturing works in these formations and why success has been limited to date. IGT recommends $1 million to study the effect of relaxation channels on gas production and the dependence of permeability on compressive stress for several gassy coals by adapting existing laboratory equipment.

- In the geopressured methane area, the ability to predict gas content and long-term co-production of gas and hot brine requires extensive testing to accumulate accurate experimental information needed for data correlation. IGT recommends $5 million for the collection of definitive data from the existing design wells and $1 million for adapting existing laboratory equipment to measure critical gas saturation and relative permeabilities to gas and brine.

- Present knowledge, though very limited, indicates the potential for extensive deposits of methane hydrates in the Arctic deep ocean sediments. IGT recommends $0.5 million for the laboratory investigation of the formation and behavior of methane hydrates under natural conditions.

## BIOMASS

- IGT recommends $1 million to determine reactant requirements, product specification, environmental impact, and overall economics of the RENUGAS process in an existing pressurized fluidized-bed process research unit built with DOE funds. The RENUGAS process converts biomass and waste thermochemically to fuel gas or synthesis gas.
- $0.25 million to investigate the gasification behavior of biomass structural components, i.e., cellulose, hemicellulose and lignin.
- $0.5 million to investigate the catalytic reforming of heavy oil and tars from biomass gasifiers into lighter and more useable hydrocarbons.
- $1 million to establish the potential of an important break-through, the first known inoculum which can gasify woody biomass without prior treatment.
- $1 million to design, construct and operate a process research unit to determine digester performance and perform process evaluation for the conversion of giant brown kelp into fuels and chemicals.
- $0.5 million for bioassay screening and bench-scale digestion tests to determine the methane production potential of a wide variety of microalgae species.
- $0.5 million for the co-production of fuels and chemicals for biomass using biological organisms.
- In waste conversion, IGT has achieved in its two-phase digestion laboratory studies twice the production of methane per unit of waste compared to single-phase digestion technologies. IGT recommends $1 million to construct and operate an on-site process research unit for the two-phase digestion of municipal sewage sludge using a novel upflow solids digester.
- $0.5 million for testing the LANFILGAS process for biologically digesting landfills through a two-phase, leachate recycle approach

## FUEL CELL

In the molten carbonate fuel cell area, IGT specifically recommends $6 million to initiate a multi-year program on technology base expansion which focuses on using existing facilities for evaluating components, testing prototype endurance, measuring effects of contaminants, and preparing electrolytes in a controlled environment. The MCFC system has potentially the best combination of performance, efficiency, and cost for applications in power generation and co-generation.

CONSERVATION

- IGT recommends $1 million to develop an indoor air quality model based on its existing comprehensive air infiltration model and to evaluate various alternative strategies for indoor air quality control.
- $2 million to initiate a program to build and test in the laboratory the H-COP concept for residential heating and cooling. This is an advanced high-efficiency concept based on a gas-fired, open-cycle, solid-desiccant system that can be coupled with a solar energy source.
- $1 million to initiate a program to build and operate the combined-cycle heat pump test unit based on IGT's Hyperabsorption cycle.
- In industrial conservation, IGT recommends a $3 million program to develop a proof-of-concept facility for a thermochemical recuperative system to evaluate design parameters, conversion rates, and materials compatibility. Such a system could double the waste heat recovered from high-temperature industrial furnaces.
- $0.5 million to develop an advanced analytical model for high-efficiency adiabatic diesel engines.
- A cyclonic melter or furnace with twice the efficiency of today's most advanced industrial furnace has wide application in the glass melting and mineral ore processing industries. IGT recommends $2 million to perform bench-scale development work of the cyclonic melter to lead to the design of the prototype unit.
- $1 million to develop a novel advanced combustor which has the heat exchange surfaces located directly in the combustion zone of the burner.
- $0.5 million to initiate investigations of an advanced firetube aluminum melter
- $1 million to experimentally evaluate the kinetics, product purification, process/energy source interface and engineering optimization of three promising hybrid cycles for hydrogen production via the thermochemical splitting of water.

THERMAL AND MECHANICAL ENERGY STORAGE

- IGT recommends $4 million for the intensified development of thermal energy storage using composite molten-salt phase-change materials. Proof-of-concept testing is now underway for industrial applications of this technology which has wide application from thermal installations to utility load management.

ATTACHMENT 2
TO STATEMENT BY BERNARD S. LEE
March 8, 1984

## GASIFICATION

### Coal Gasification

#### Pressurized Ash Agglomeration Process Research Unit

The ash agglomerating fluidized bed permits excellent conversion efficiency with any type of coal, even low quality, high-ash, high-sulfur, highly-caking coals, as evidenced in the U-GAS process for producing medium-Btu industrial fuel gas. It is necessary to extend the existing data base to 500 psig — the pressure level required for combined cycle power generation and for the production of methanol, SNG, and chemicals. IGT is now operating its own 500-psi, 8-inch diameter Process Research Unit (PRU) to obtain data on the effects of pressure, temperature, and carbon concentration on the ash agglomeration qualities of an Illinois basin coal. Further experimentation is needed to extend high-pressure ash agglomeration to lignites, subbituminous, and other high-sulfur bituminous coals. We must expand our data base to include basic process understanding of the gasification kinetics, trace component formation, and ash characteristics as these are influenced by pressures in the 500-psi range. IGT will bring significant contributions to this project by providing the use of its unique PRU and many other related equipment and facilities, and anticipates substantial funding by the Gas Research Institute with DOE to carry out this program.

IGT recommends $6 million to continue operations on the high-pressure 8-inch diameter PRU so that the ash U-GAS agglomerating fluidized bed gasification technique can be extended to 500 psi for all types of U.S. coals.

#### Technology Base Research

o The production of fines by both chemical and mechanical action in a fluidized bed is a major process factor in the development of this technology. Fines blown from the bed must be collected and recycled several times to achieve high carbon conversions. The presence of fines in the product gas creates mechanical problems in downstream processes, especially in combined cycle power generation. Detailed data are necessary to understand and minimize the cause of fines productions under realistic operating conditions.

IGT recommends $1 million for the operation of any existing high-pressure, high-temperature fluidized bed Advanced Multipurpose Research Reactor (AMRR) to obtain specific data on the chemical and mechanical causes of fines production in fluidized bed gasifiers.

o The reactions of ionized gas with coal can produce intermediate chemical species which, if identified, will provide valuable data on the kinetic mechanisms occurring during the initial stages of gasification at the very surface of the coal. Understanding these fundamental reactions can increase the efficiency and decrease the cost of coal gasification processes. Similar techniques are being used in the biomedical field to determine the surface chemistry and structure of vitamins and carbohydrates.

IGT recommends $0.5 million to extend the ion impact technique for determining the chemical structure of intermediate kinetic species to coal gasification using existing high resolution analytical equipment.

o Further advances in our surface coal gasification technology can be realized through a more fundamental understanding of the mechanisms by which coal is converted to gaseous and liquid end products. Isotopes of the heteroatoms, sulfur, nitrogen, and trace element contaminants, can be used as labels to trace the fate of the key structural elements in coals as they undergo fragmentation and substitution reactions. Such research will also provide the basic data needed to economically and efficiently process these contaminants in an environmentally acceptable manner.

IGT recommends $0.5 million to extend isotopic labeling technique to the major heteratoms of sulfur, nitrogen, and oxygen in coal to better control the conversion mechanism of these potentially contaminating elements in future coal gasification technologies.

o The understanding of ash behavior and chemistry during gasification is essential to the design of ash agglomerating gasifiers. It is, therefore, necessary to obtain data establishing the effects of temperature, pressure, size, and composition on the kinetics and mechanics of coal ash particle agglomeration in the 1800°-2500°F temperature range.

IGT recommends $1 million to continue the fundamental research on coal ash behavior using an existing novel needle penetrometer and high-pressure hot-stage microscope to obtain data in the ash agglomeration temperature regime.

o Generic physical property data are needed to allow for proper design of coal gasifier raw product handling systems. In the rapid cool-down (or quench) step, some of the components such as hydrogen sulfide and ammonia, in the product gas stream condense. Some of the products enter the waste water treatment system. The lack of data for predicting the condensing behavior of these compounds leads to costly ove-design of the quench and environmental control system.

IGT recommends $0.5 million for determining the multicomponent thermophysical properties of gasifier effluent streams in existing laboratory equipment capable of analyzing the concurrent condensing behavior of hydrogen sulfide and ammonia.

o Past research at IGT has identified several promising sorbents for the removal of chemical contaminants from coal-derived fuel gases at elevated temperatures and pressures. These composited mixed metal oxide sorbents can remove sulfides, mercaptans and halides. The contaminants adversely affect the performance of combined-cycle power turbines, catalytic reactors, and fuel cells; hence, they must be removed for the successful application of coal gasification technology to these areas. Further research is needed to validate the long term performance of these composite sorbents in a continuous laboratory research unit.

IGT recommends $1.5 million for the construction and operation of a high-temperature, high-pressure bench-scale research unit to continue the development of composite sorbents for removing sulfide and halide contaminants from coal gasifier effluent streams.

o Basic research is under way on a novel biological technique for upgrading raw gasifier effluent gases to sulfur-free fuel gas. A two-step biological process first converts synthesis gas to methane and then removes sulfur contaminants. This process operates at low pressures and temperatures and eliminates the need for costly hot pressurized catalytic shift and methanation reactors. Further laboratory research is necessary to determine preferred culture concentrations and optimize digester size and gas throughput rates.

IGT recommends $1 million to continue the laboratory research of a novel two-step biological technique for upgrading raw gasifier effluent gases.

o Wet carbonization is an effective method for beneficiating low-rank coals. The use of beneficiated coals can significantly improve the efficiency of coal gasification. To determine the gasification reactivity characteristics of the carbonized coal, laboratory data must be validated with a bench-scale experimental test unit capable of gasifying the prepared coals over a wide range of operating conditions.

IGT recommends $2 million to determine the gasification characteristics of wet-carbonized coals produced from an existing wet-carbonization process research unit.

o The feeding of solids into and the discharging of residues from pressurized coal gas plant reactors continues to be a major capital and operating cost. Conventional pneumatic lockhopper systems utilize product gas or inert gas as the pressurizing medium, resulting in high gas compression costs, loss of valuable product gas and mechanical valve sealing problems. Use of liquid (non-compressible fluid) filled hoppers has the potential to eliminate most of the problems associated with the pneumatic lockhopper. Particulate solids in the feed and discharge hopper displace a non-compressible fluid (usually water). A special patented dewatering screw feeder delivers drained solids from the top feed hopper to the reactor while a similar device delivers drained residue from the reactor. It is critical to deliver drained solids with very low liquid content to the gasifier. Previous experimental work with large lumps has demonstrated the feasibility of the process. Additional experimental work on the range of allowable particle sizes, the drainability of the particles and the capacity limits of the system must be done to fully develop the concept.

IGT recommends $1 million to examine the range of applicability of the liquid-sealed lockhopper.

o DOE has invested several years of effort in accumulating much basic data on the thermodynamic and physical properties of a myriad of hydrocarbon compounds. These basic data are needed as input to computerized design packages that allow rapid calculation of process stream composition, energy and material balances, and reactor sizes. A need exists to collect, categorize, and evaluate this data and be put into a format that will be readily compatible with state-of-the-art computerized design calculation software. Additional basic data requirements would be easily identifiable as a result of this effort, which should be continued for several years.

IGT recommends that initial funding for this program be at a $1 million per year level of effort.

## Shale Gasification

Current retorting technologies for U.S. oil shale discard unretorted fines and potentially leachable residues that present environmental problems. These materials contain carbon which amounts to as much as 50% of the total energy available in the shale as mined. These shale materials can be gasified in an ash-agglomerating, fluidized bed to produce additional gaseous energy while simultaneously immobilizing potentially leachable material in the form of environmentally benign, non-leachable spent shale agglomerates.

IGT recommends $1 million to operate existing gasification equipment to develop the ash-agglomerating, fluidized bed technique for gasifying and recovering the carbon in shale discards and producing environmentally benign, non-leachable spent shale agglomerates for disposal.

## UNCONVENTIONAL AND GEOPRESSURED RESOURCES

### Eastern Devonian Shale

The key to the reliable assessment of this potential energy supply lies in the predictive capability which requires accurate determination of the rock properties. The work now being conducted on Devonian shale rock permeability and porosity in the IGT Computer-Operated Rock Analysis Laboratory (CORAL) indicates that each sample may have to be in the measurement apparatus for several weeks before quantitative measurements representative of in-situ reservoir rock can be obtained. Timely progress in this vital area dictates that additional experimental equipment be constructed to expand the capability of the existing CORAL laboratory.

IGT recommends $1 million to expand the CORAL laboratory and to provide operating funds for the continuation of these rock property measurements.

### Western Tight Sands

The current work on the Multi-well Experiment (MWX) core samples has provided a deeper understanding of the characteristics of gas reservoirs and adjacent strata. The stimulation and production tests planned for 1984 will provide the first basis for comparing post-hydraulic fracture production with predictions based on reservoir rock properties. The continuing program for research in tight sands should emphasize long-range research on the measurements of reservoir rock properties as well as refinements in computer simulation techniques needed to improve the predictive capabilities for estimation of reserves and production.

IGT recommends $1.5 million to examination of the MWX cores in CORAL and to augment core analyses in the Experimental Tight Rock Analysis (EXTRA) equipment so that existing predictive computer models using the measured physical property data can be compared with actual production data.

### Methane from Unmineable and Interbedded Coal Seams

Continuing IGT research on coal bed methane production has led to the first understanding of how hydraulic fracturing works in these formations and why success has been limited to date. Because of the physical nature of coal beds, hydraulic fracturing increases compressive stress adjacent to the fracturing formations, thus reducing the permeability. Continued research is needed to test the effect of compressive stress on permeability and to investigate various means of producing long "relaxation" channels in the coal bed.

IGT recommends $1 million to study the effect of relaxation channels on gas production and the dependence of permeability on compressive stress for several gassy coals by adapting existing laboratory equipment.

## Geopressured Methane

Production of hydrocarbons must exceed solubility in reservoir brine if production economics are to be favorable for the pressures and temperatures of wells tested to date. If the brine initially produced is not saturated at reservoir pressure and temperature, it is unlikely that greater hydrocarbon production will occur from that reservoir. It is therefore recommended that sampling, sample analysis, and test instrumentation for existing design wells be upgraded as appropriate to resolve existing discrepancies in well test results and laboratory studies of hydrocarbon solubility.

Funds should be appropriated for testing of the higher temperature, higher pressure Willis Hulin No. 1 well. In addition, the scope of research on energy production with high brine rates should be expanded to include hydropressured, as well as geopressured, reservoirs.

IGT recommends $5 million for the collection of co-production data from existing design wells and $1 million for adapting existing laboratory equipment for measuring critical gas saturation and relative permeabilities to gas and brine with the accuracy required to predict gas production from both geopressured and hydropressured wells.

## Methane Hydrates

Present knowledge, though very limited, indicates the potential for extensive deposits of methane hydrates in the Arctic and deep ocean sediments. This hydrate may in some circumstances also serve as a trap for gaseous methane. It is important to assess the location, magnitude and possible economic recovery of these resources. To this end a comprehensive multi-year research program, both laboratory and field, should be undertaken.

IGT recommends $0.5 million for the laboratory investigation of the formation and behavior of methane hydrates under simulated natural conditions. By adapting existing high pressure rock analysis equipment, gas hydrates formation can be simulated in ice and in their sediments. This increased understanding combined with diffusion rate measurements of the gas released from the hydrate would lead to characterization of this reservoir and the tailoring of tools to recover this energy source economically.

## BIOMASS

### Biomass Conversion

o Pressurized steam-oxygen or steam-air thermal gasification is a very attractive route to produce useful energy from biomass. The existing IGT RENUGAS Process Research Unit (PRU) built with DOE funds was specifically designed to obtain accurate scale-up data on the thermal conversion of biomass via pressurized fluid-bed gasification to medium-Btu fuel gas or synthesis gas for the production of substitute natural gas, methanol, or other transportation fuels. The PRU operates adiabatically and is of sufficient size (12-in. I.D.) that gasification data can be accurately scaled to commercial size applications.

IGT recommends $1 million to determine reactant requirements, product specification, environmental impact and overall economics of this approach to biomass energy conversion using the high-pressure, adiabatic, steam-oxygen RENUGAS PRU.

o Woody biomass is considered to be the most appropriate feedstock for the production of substitute fuels or synthesis gas by thermal gasification. Most of the wood species have similar elemental composition, when expressed on a moisture and mineral matter free basis, but they differ in their structural composition, i.e., cellulose, hemicellulose, and lignin contents. Since nearly 80% of the biomass undergoes rapid devolatilization during thermal gasification, the distribution of these structural components determine the product gas composition. For example, lignins contribute to the production of direct methane while cellulose produces carbon monoxide and hydrogen. Bench-scale experiments are needed in existing laminar flow and thermobalance reactors to develop consistent solvent extraction methods to isolate the biomass structural components in different woody biomass species and to determine their devolatilization and char gasification behavior. Correlating the distributions of biomass structural composition and the devolatilized products would form the basis for recommending the most desirable feedstocks for medium-Btu or synthesis gas production. This information would also direct genetic engineers in the cultivation of new biomass species optimized for thermal gasification.

IGT recommends $0.25 million to investigate the gasification behavior of biomass structural components.

o Biomass gasifiers, the moving-bed gasifiers in particular, produce heavy oils and creosote tars which can cause mechanical operability problems as well as requiring special processing equipment to assure environmental acceptability of the process effluent. Biomass gasification processes would benefit from elimination of these heavy oil and tar products. Bench-scale experiments are needed to determine the effect of inexpensive and disposable alkaline metal-oxide catalysts on the decomposition of heavy oils and creosote tars into simpler hydrocarbon species. The bench-scale data would then be analyzed to identify effective catalysts and to develop process concepts for heavy oil and tar decomposition.

IGT recommends $0.5 million to investigate the catalytic conversion of biomass gasifier liquid products.

o IGT has developed the first known inoculum that can convert untreated woody biomass to methane by anaerobic digestion. This method of gasification could have the advantage of producing a high quality gas with few contaminants at a low cost. Woody biomass has a major advantage over other renewable energy forms in that it can be grown with high yields at a variety of locations in the U.S. Research should include a screening of a variety of different woody species to determine their biodegradability, gasification potential, and reactivity as a function of growth and harvest conditions. Laboratory and bench-scale studies should be conducted to determine the best reactor type and operating conditions for maximum conversion of wood to methane. This research will provide data needed for process design, scale-up, and economic assessment.

IGT recommends $1 million to genetically improve the IGT wood digestion inoculum, determine conditions optimum for its growth and metabolism, and develop a process to convert woody biomass to usable fuel gas.

o Giant brown kelp, grown in California coastal waters, has been shown to be highly amenable to anaerobic digestion for methane production. The species has demonstrated high methane yields and production rates during very stable fermentation in an upflow solids reactor. These laboratory studies need to be supported by testing in a continuous bench-scale process research unit to validate digester performance and evaluate equipment for continuous feed preparation and effluent handling. The final process scheme, selected as a result of these studies, will be operated as an integrated unit to permit optimization of the final conceptual process design and to provide a data base for detailed system analysis.

IGT recommends $1 million to design, construct and operate a process research unit to determine digester performance and perform process evaluations.

o Microalgae have a high potential for energy and chemical applications because they exhibit rapid growth, high yields, and most species are not needed for other applications in the U.S. A screening program is recommended to collect, analyze and evaluate the suitability of various microalgal species for conversion to methane. Ongoing growth programs should be identified as a source of microalgae with well-documented genetic and environmental data. The biogasification potential of these feeds should be examined using established anaerobic bioassay techniques to assess biodegradability and methane production to select a prototype species for further study. Process variables with the potential to influence methane production rates and yields should then be evaluated to develop a data base for bench-scale digester operation.

IGT recommends $0.5 million for bioassay screening and bench-scale digestion tests to determine the methane production potential of a wide variety of microalgae species.

o During the process of decomposing biomass or organic waste, microorganisms produce various products that may be useful as fuel or industrial chemicals. Two such well-known fuels are methane and ethanol. Based on work conducted at IGT, biotechnology research has demonstrated that production of other chemicals such as hydrogen, acetic acid, acetone, butanol, methanol, and processed lignin is possible. The production of these chemicals via microbial conversion of biomass and waste represents a potentially economic and environmentally desirable option. A balanced basic and applied research program is needed to develop the organisms and optimize the growth conditions for production of these fuels or chemicals.

IGT recommends $0.5 million to conduct basic and applied research on the biological coproduction of fuels and chemicals from biomass.

## Waste Conversion

o Current IGT research in its two-phase digestion process with municipal sewage sludge has produced 7.5 cubic feet of methane for every pound of dry organic matter processed, about twice what current single-phase digestion technologies can produce. A novel upflow solids digester is showing high promise as the digester type to be used for processing sludge. The next logical step is to construct and operate a continuous, adiabatic larger scale process research unit. Continuous on-site testing is necessary to prove the upflow reactor concept.

IGT recommends $1 million to construct and operate an on-site PRU to provide proof-of-concept data for the two-phase digestion process for municipal sewage sludge.

o Two-phase biological digestion can also be used to recover energy from solid waste landfills. IGT's LANFILGAS process uses controlled recirculation of an aqueous phase bacterial culture to stabilize the organic waste within the landfill and to produce methane by two-phase digestion of leached organics in the recirculating liquid culture. The process can be applied to large as well as small landfills. Small-scale laboratory data indicate the technical feasibility of the concept. Further data are needed at the bench-scale level to study the effects of culture recirculation rate, digester temperatures, and hydraulic and solids retention times in the acid-phase and methane-phase digesters.

IGT recommends $0.5 million to conduct two-phase, leachate recycle, proof-of-concept tests on an existing landfill.

## FUEL CELLS

### Molten Carbonate Fuel Cells

The molten carbonate fuel cell (MCFC) operating on gasified coal, reformed hydrocarbons or internally reformed methane can provide an efficient, low-cost solution to our future needs in power generation. Not only can it serve the central station and dispersed power sectors but, using natural gas, can yield a high efficiency cogeneration system for industry. IGT is preeminent in MCFC technology and maintains laboratory and development facilities for fuel cells and the related technologies of gasification and gas clean-up systems.

IGT proposes a multi-year program, and recommends the following $6 million program in FY'85 for technology base expansion:

o Utilize existing facilities and capabilities to develop, test and evaluate innovative fuel cell components such as the electrolyte, anode, reforming catalyst for internal reforming cells, and the cathode and bipolar plate; endurance testing of bench-scale cells and stacks of cells; and carbonate management schemes and stack design. Using existing DOE facilities for testing prototype endurance, for measuring the effect of contaminants on cell performance, and for electrolyte preparation in a controlled environment would be cost effective and would provide impartial dissemination of information on cell life and performance directly to all potential manufacturers.

o Basic electrochemistry and accompanying support studies that seek improved cell performance and endurance.

o Systems analysis of power plant designs and configurations, including performance modelling, gasifier selection, feasibility of anode gas recycle and establishment of fuel tolerance.

## CONSERVATION

### Building and Community Systems

o Following the enactment of the Source Emission Standards and National Ambient Air Quality Standards covering outdoor air contaminants in the early 1970's, attention has now been directed toward indoor air quality and its relation to indoor air pollution epidemiology. It is generally agreed that indoor air quality is a complex function not only of outdoor pollutant concentrations, building permeability, internal generation, and meteorological conditions, but also of contaminant control measures, control equipment design and, more recently, energy conservation measures. By far, the most important subroutine required for an integrated air quality model is a model for air infiltration.

IGT recommends $1 million to develop an indoor air quality model based on IGT's existing comprehensive air infiltration model and to evaluate various alternative strategies for indoor air quality control including air-to-air heat exchangers, spot ventilators, air cleaning devices.

o An advanced gas/solar or gas-only desiccant system, the H-COP, was developed by IGT for residential heating and cooling. This design features a 95% efficient heat exchanger wheels and advanced reactivation design. The calculated seasonal "energy efficiency ratio" (EER) is twice that of commercially available air conditioning systems, and the projected cooling performance exceeds that of other systems now under development by more than 50%.

IGT recommends $2 million to build and test laboratory scale H-COP concept in a configuration designed for residential use, including a gas-only and gas/solar firing. This unit would allow for improved desiccant and desiccant support research, advanced burner development, and advanced control system development.

o Because of less than adequate heat actuated heat pump performance by well-known mechanical power cycles (Rankine, Stirling, Brayton, Otto) and single-effect absorption concepts in providing efficient comfort control, emphasis has shifted to combined-cycle mechanical heat pumps (Vuileumier, Ericsson-Ericsson, or Stirling-Stirling) and high efficiency absorption cycles (such as IGT's Hyperabsorption Cycle) because of the promise of achieving nearly 90% of their theoretical efficiency limits.

IGT recommends $1 million to initiate a program to design, engineer, fabricate, and evaluate a 3-ton combined-cycle heat pump test unit based on IGT's Hyperabsorption Cycle.

o Recently, developments in small, stationary automotive prime movers have been directed toward improved fuel economy, decreased emissions, and improvements in operating characteristics such as dynamic response, proper ratio of maximum to nominal torque. For diesel engines, the combination of a decrease in heat loss and associated heat recovery offers better improvement potential for adiabatic diesel engines than improvement of the combustion process within the cylinder,according to assessments at IGT with screw compressors and expanders.

IGT recommends $0.5 million to complete the development of an analytical model to evaluate the performance of screw compressors and expanders as they relate to diesel engines and to study the influence of design changes on system performance. The model development will include dynamic effects and provide insight into the feasibility of manufacturing processes employing advanced ceramic or composite materials.

## Industrial

o A novel thermochemical recuperative system (TCRS) should be developed that can greatly increase waste-heat recovery in high-temperature industrial furnaces, such as in the fiberglass and steel industries. State-of-the-art metallic recuperators are limited to about 1500°F in air preheat. Work is underway to develop ceramic heat exchangers to increase this to 2000°F. The TCRS, however, uses no exotic ceramics. Instead, it recuperates the high-temperature waste-heat into both the combustion air and fuel via the thermochemical conversion of natural gas with steam. The resulting synthesis gas mixtures, when combusted with air preheated by state-of-the-art technology, is equivalent to an air preheat of 2600°-2900°F.

The TCRS offers waste-heat recovery efficiencies exceeding 70% as compared with only 30% to 40% for conventional recuperation, provides fuel savings of up to 30% above that achieved by conventional recuperation, increases furnace production rate and improves product quality, and reduces $NO_x$ emmission per unit of product.

IGT recommends $3 million to construct and test a proof-of-concept facility of the TCRS to evaluate design parameters, conversion rates, and materials compatibility. The results will lead to a test program of a large scale prototype at an industrial site.

o A cyclonic melter or furnace with an efficiency of 80%, contrasted with the 40-45% efficiency of today's most advanced industrial furnaces, is the goal of this program. Features of the proposed furnace are: extremely high melting intensity, and separation of combustion products from melt.

The melter would have wide industrial applications in glass melting, phosphate rock melting, chromium ore melting, mineral wool production, fiberglass manufacture, and vitreous enamel frit production.

IGT recommends $2 million to perform bench-scale development work of the high efficiency cyclonic melter, leading to the design of a prototype unit.

o An advanced combustor concept, particularly applicable to package boilers and process heaters, has been developed which locates the heat exchange surfaces directly in the combustion zone. Such a combustor would reduce the peak flame temperature substantially, thereby significantly reducing $NO_x$ formation, which is a principal pollutant in the flue- gas emissions. Furthermore, such a combustor would improve the heat-transfer rates and efficiency, and reduce the combustor size, all of which would mean substantial reduction in capital and operating costs.

IGT recommends $1 million for research and development in heat exrhange materials, flame support surface, combustion stability, and catalyst formulation in certain embodiments of the concept. The funding will enable the fabrication and operation of a prototype surface combustor to detemine performance data.

o To enhance aluminum recovery and product quality, an advanced concept for aluminum remelt can eliminate the problems of low efficiency, pollution caused by the combustion of paint associated with the aluminum, the loss of aluminum due to oxidation and the presence of hydrogen in the remelted aluminum. In this concept, the hot flame does not contact the aluminum; the fire tubes are immersed in the molten aluminum resulting in excellent heat transfer characteristics.

IGT recommends $0.5 million to initiate investigations of the advanced firetube aluminum melter. The initial work would center on the identification of materials to withstand the molten aluminum at elevated temperatures.

### Hydrogen

A leading candidate for the fuel of the future is hydrogen derived by splitting water by using high temperature energy from nuclear fission, fusion or solar sources. To accomplish this, it is necessary to continue development of thermochemical or thermoelectrochemical cycles. Three hybrid cycles have been identified on a laboratory scale as having the potential to accomplish efficient and, ultimately, cost-effective water splitting. The three involve copper sulfate-copper oxide, zinc sulfate-zinc oxide, and cadmium chemistry.

IGT supports $3 million to continue the work on hydrogen research and specifically recommends $1 million for systems evaluations, including reaction kinetics, process/energy source interfaces, product purification and engineering optimization of the cycles.

## THERMAL AND MECHANICAL ENERGY STORAGE

### Thermal Energy Storage

Thermal energy storage benefits both energy efficiency and capital and operating costs. It can recover and store the energy exhausted in many processes for reuse, thus reducing primary fuel requirements, and it can improve the load factor of utilities by reducing added capacity requirements. IGT is developing a family of phase-change composite thermal storage media that allows direct-contact heat transfer. This concept has a wide range of applications from themal installations to utility load management. Significant cost benefits have been projected for these composite systems compared to conventional sensible heat storage systems. Proof-of-concept testing is now underway for industrial applications. Expanded R&D is needed in the identification of technical and economic goals for potential markets, measurement of physical and chemical properties of potential media materials, optimization of media thermal and physical behaviors within expected operating conditions, media selection/development to fit application temperatures and operating requirements, and study of materials compatibility between media, containment, working fluids, and auxiliary components.

IGT recommends $4 million for the intensified development of thermal energy storage using composite molten-salt phase-change materials.

Mr. **Fuqua**. Thank you very much.

Dave, we will be happy to hear from you at this time.

Mr. **Webb**. Thank you, Mr. Chairman, members of the committee.

I appreciate the opportunity to appear before you today to discuss the Gas Research Institute's views and fiscal year 1985 budget recommendations necessary to allow the Department of Energy to continue critical, long-term gas-related research programs. The gas industry is recommending a total of $150 million for gas-related research in the DOE budget. We are recommending $97 million for gas-related research for DOE's Fossil Energy Program, $22 million for DOE's Conservation Program, and $31 million for DOE's Solar and Renewables Program.

GRI co-funds and coordinates many of its research programs with DOE; therefore, the actions of Congress on the fiscal year 1985 DOE budget have a direct impact on the gas industry's research program.

I recognize in today's environment of limited financial resources and large Federal budget deficits, that competing requests for Federal support and funding must be carefully evaluated and hard choices made. Therefore, before I summarize specific budget recommendations, I will discuss five key factors GRI used for establishing the priority and evaluating the reasonableness of our recommendations.

One: Is the DOE budget request for gas research consistent with congressional actions over the past 3 years? The DOE fiscal year 1985 budget request for gas-related research is not consistent with congressional policy as it is only approximately 65 percent of the level approved by Congress for fiscal year 1984 just 5 months ago.

Two: Has the gas industry increased its own research program with emphasis on near-term research? In contrast to the inconsistency in Federal policy and the reduced DOE funding for gas research, the response of the gas industry to the revised R&D policy has been rapid and very impressive. GRI's research program and budget has grown from $80.5 million in 1981, the first year the Federal policy shifted responsibility for near-term research to industry rather than DOE, to $140 million in 1984. This growth is even more impressive when you consider that the gas industry in 1983 sold less gas than any year since 1967. The gas industry is keeping its commitment to research.

The gas industry, through GRI, has been totally responsive to Federal policy by focusing on near-term research and increasing its total budget by 75 percent over the past 4 years.

Three: Is the DOE budget request balanced or is it biased toward specific technologies? An examination of the DOE fiscal year 1985 budget request reveals that again the budget is tremendously biased in favor of electric technologies with particular emphasis on nuclear. This bias toward funding electric-related research of greater than 15 to 1 compared to funding of gas research has been evidence in the DOE budget for the last 10 years and conflicts with the Department's policy.

The DOE budget is not balanced and is strongly biased toward funding electric options.

Four: Are there institutional barriers that limit the regulated gas industry's ability to fund R&D? DOE's Energy Research Advisory Board—ERAB—in a report to the Deputy Secretary of Energy, put these factors in proper perspective in its study, "Federal Energy R&D Priorities."

> A little over half our primary energy finds its way to consumers through the electric and gas utilities, and the utilities are regulated, price-controlled industries, selling their products not at free market prices, but at controlled prices well below replacement cost. . . . Both these regulated industries have weak incentives to spend on R&D. If successful, the benefits go to ratepayers; if unsuccessful, the expenditure may be disallowed as "imprudent."

DOE, in its fiscal year 1985 budget request, recognized this structural problem for the electric utilities by proposing a total electric-related research budget of approximately $1,320 million. However, they totally ignored these same institutional and structural deficiencies for the regulated gas industry by proposing only $83.7 million for gas-related research. A ratio of over 15 to 1 is not sound national policy. This imbalance must be corrected by funding a viable gas-related research program.

Five: Are the gas industry's fiscal year 1985 budget recommendations consistent with Federal policy and congressional direction?

When you evaluate the gas industry's budget recommendations, you will find they are in the national interest, consistent with Federal policy, and essentially identical to the actions taken by this subcommittee and Congress in approving the DOE fiscal year 1984 budget.

At the end of my testimony is a table that provides details on the specific programmatic funding recommendations. However, Mr. Chairman, let me briefly mention five important long-term research recommendations that require Federal support to continue joint DOE/gas industry projects.

Of particular importance is the development of advanced processes that can use high-sulfur eastern coals and coal fines. For several years, GRI and the Department of Energy jointly supported the initial development of several advanced gasification processes. In 1981, test results and technical and economic evaluations justified our concentrating on the further development of the agglomerating ash fluidized bed process. Federal support in fiscal year 1985 of $7 million is needed for further development of the Westinghouse process at Waltz Mill to continue PDU tests, cold-flow test facility operations, and laboratory research with an emphasis on environmental aspects.

Continued testing and operation of the pressurized ash agglomeration process at IGT is required to extend the technology to additional high-sulfur bituminous coals. A total of $6 million is recommended to continue these tests.

Within the $20 million recommendation, the gas industry urges that $4.5 million be committed to research in eastern Devonian shales; $7 million for western tight sands; $5 million for methane from coal seams; and $3.5 million for advanced unconventional and environmental research.

The gas industry and GRI have made a major commitment in funding for on-site phosphoric acid fuel cell systems—from $11.3 million in 1982 to $19.6 million in both 1983 and 1984—to offset the loss of DOE funds for near-term research. The Gas Research Institute has now totally assumed the cost of the joint DOE/GRI program to field test the 45 phosphoric acid fuel cell units.

The technology development program now being pursued under a joint effort with DOE and GRI is for the purpose of increasing reliability and lowering the costs of these on-site systems. On August 18, 1982, DOE initiated a 4-year, $20 million program for this research with the manufacturer, United Technologies Corp. [UTC] that requires a DOE commitment of $6 million in fiscal year 1985. The DOE work concentrates on the fuel cell stack; the fuel processing system, including catalyst research; the inverter; and specialty heat exchangers.

Specific technology-based research is needed on an advanced gas prime mover and compressor necessary to produce a competitive heat pump for residential and commercial markets by 1990. To achieve this goal requires an expanded DOE program of $7 million in fiscal year 1985.

Several attractive long-term technologies, specifically free-piston Stirling engines, free-piston internal combustion engines, and double-effect absorption cycles, show a good probability of providing the reliable, long-life, high-efficiency operation required of heat pump systems.

To balance the recommended DOE program, GRI is planning to spend $5 million in both 1984 and 1985 for near-term research on these programs.

The unique advantages of biomass make it an excellent candidate for many regions of the United States that lack conventional energy resources. To provide a model for developing biomass energy programs on a regional basis, GRI began a program with the University of Florida's Institute of Food and Agricultural Sciences in 1982. GRI has other related programs in the Northeast with the New York Gas Group and the New York State Energy Research and Development Authority, and in the Southwest with Texas A&M University. All of these are cofunded efforts. We anticipate that many of the results are transferrable to other parts of the country. DOE should expand the regional biomass concept by providing $4 million in the fiscal year 1985 budget.

In terms of DOE-supported research, it should be directed in the next 10 years to demonstrate at a reasonably large scale key elements of a regional biomass-to-methane system so that we have confidence in the attendant economics. This research should center on biotechnological advances that permit the manipulation of both the feedstock and the microorganisms used in the bioconversion process. Thus, using technically proven methods for cloning, infusion of genetic material into living cells, and conventional genetics, one can improve the characteristics of a plant for growth, for disease resistance, for the ability to fix nitrogen, and for a specific conversion process. One can simultaneously adapt the biological organisms of the conversion process to produce a more efficient system. With improved biomass feedstocks through bioengineering and other techniques, a cost-competitive energy system should begin to emerge.

The gas industry recommends that $12.5 million be used for biomass conversion, $1.5 million for waste conversion technology, and $2 million for research on biomass growth and harvesting.

### SUMMARY AND RECOMMENDATIONS

A viable Federal program consistent with administration energy policy requires a budget in fiscal year 1985 for a long-term gas research program of approximately $150 million. It should be noted that this recommendation continues the programs approved by this subcommittee and Congress for gas-related research over the past 2 years and is approximately the same as appropriated by Congress just 4 months ago for the fiscal year 1984 funding level.

Thank you very much, Mr. Chairman. I would be glad to respond to questions after we finish the panel.

[The prepared statement of Mr. Webb follows:]

# STATEMENT OF DAVID O. WEBB, SENIOR VICE PRESIDENT
# POLICY AND REGULATORY AFFAIRS, GAS RESEARCH INSTITUTE
# BEFORE THE ENERGY DEVELOPMENT AND APPLICATIONS SUBCOMMITTEE OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY
# UNITED STATES HOUSE OF REPRESENTATIVES
# MARCH 8, 1984

Mr. Chairman and Members of the Committee:

I appreciate the opportunity to appear before you today to discuss the Gas Research Institute's (GRI) views and FY 1985 budget recommendations necessary to allow the Department of Energy (DOE) to continue critical, long-term gas-related research programs. The gas industry is recommending a total of $150 million for gas-related research in the DOE budget. We are recommending $97 million for gas-related research for DOE's Fossil Energy Program, $22 million for DOE's Conservation Program, and $31 million for DOE's Solar and Renewables Program. These budget recommendations are essentially the same as appropriated by Congress for FY 1984 and are in accord with the Administration's stated energy policy, complement the current research programs funded by the gas industry, and are consistent with the previous initiatives and leadership actions taken by this subcommittee and Congress to insure a viable long-term gas research program in the Department of Energy.

GRI is an independent, not-for-profit scientific research organization created by the gas industry in 1976 to plan, finance, and manage an expanded and fully coordinated gas-related research and development (R&D) program for the mutual benefit of the regulated gas industry and its ratepayers. In compliance with stipulated procedures, GRI submits its annual plan and five-year R&D program to the Federal Energy Regulatory Commission (FERC) for review and approval as part of a public proceeding. GRI cofunds and coordinates many of its research programs with DOE; therefore, the actions of Congress on the FY 1985 DOE budget have a direct impact on the gas industry's research program.

The need for a balanced, consistent federal policy that provides adequate funding for long-term gas research is absolutely essential if industry is to assume the near-term research previously funded by the federal government. Industry requires a stable and consistent federal base against which to plan its own research programs.

If we consider that the U.S. will continue to rely on gas and oil for over 70 percent of its energy needs in the year 2000, then the necessity for adequate long-term federal gas-related research is obvious. As we approach the year 2000, adequate gas supplies will depend on development of advanced technology necessary for the successful conversion of supplemental sources. Establishing the required technology base to develop these supplemental gas supplies at cost-competitive prices requires a lead time of six to fifteen years depending on the resource. In other words, we must start now.

I recognize in today's environment of limited financial resources and large federal budget deficits, that competing requests for federal support and funding must be carefully evaluated and hard choices made. Therefore, before I summarize specific budget recommendations, I will discuss five key factors GRI used for establishing the priority and evaluating the reasonableness of our recommendations.

**1. Is the DOE budget request for gas research consistent with congressional actions over the past three years?**

Congress, during its review and approval of the DOE budget during the past three years, has consistently added funds to the Fossil Energy, Solar, and Conservation programs to continue long-term research projects in coal gasification, onsite fuel cells, unconventional natural gas, biomass, industrial cogeneration, and heat pumps. Last year Congress more than doubled funding for the Fossil, Solar, and Conservation budgets and provided approximately $132 million for gas-related research. This year's DOE budget requests only $84 million in these programs for gas-related research and omitted funds necessary to continue many critical ongoing projects.

CONGRESSIONAL APPROPRIATIONS FOR DOE GAS-RELATED RESEARCH
($ Millions)

|  | FY 1982 | FY 1983 | FY 1984 | DOE Request FY 1985 |
|---|---|---|---|---|
| FOSSIL ENERGY |  |  |  |  |
| Advanced Research and Technology Development | $ 12.5 | $ 7.4 | $ 12.00 | $ 12.00 |
| Surface Coal Gasification | 53.1 | 39.0 | 36.80 | 15.00 |
| Underground Coal Gasification | 8.3 | 6.0 | 6.00 | 5.85 |
| Unconventional Gas Resources | 8.7 | 13.9 | 13.50 | 8.55 |
| Fuel Cells (Gas-Related) | 5.6 | 14.0 | 16.20 | 7.90 |
| Eastern Oil Shale Gasification |  |  |  | 0.00 |
| LNG Safety | 6.3 | 3.5 | 3.25 | 2.00 |
| SUBTOTAL | $ 94.5 | $ 83.8 | $ 87.75 | $ 51.30 |
| GEOPRESSURED METHANE | $ 17.3 | $ 8.4 | $ 7.00 | $ 3.50 |
| BIOMASS | $ 3.0 | $ 4.0 | $ 13.00 | $ 13.00 |
| CONSERVATION | $ 10.5 | $ 4.0 | $ 24.25 | $ 15.90 |
| TOTAL | $125.3 | $100.2 | $132.00 | $ 83.70 |

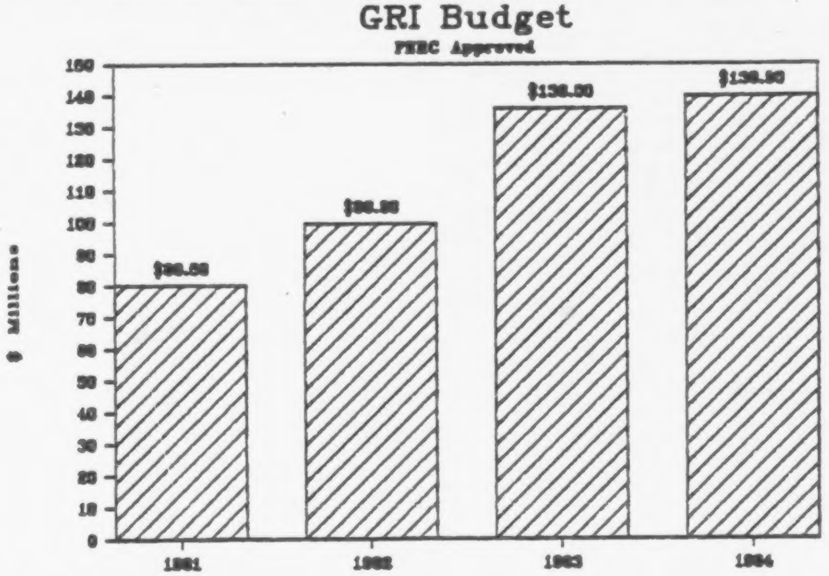
The DOE FY 1985 budget request for gas-related research is not consistent with congressional policy as it is only approximately 65 percent of the level approved by Congress for FY 1984 just five months ago.

**2. Has the gas industry increased its own research program with emphasis on near-term research?**

In contrast to the inconsistency in federal policy and the reduced DOE funding for gas research, the response of the gas industry to the revised R&D policy has been rapid and very impressive. GRI's research program and budget has grown from $80.5 million in 1981, the first year the federal policy shifted responsibility for near-term research to industry rather than DOE, to $140 million in 1984. This growth is even more impressive when you consider that the gas industry in 1983 sold less gas than any year since 1967. The gas industry is keeping its commitment to research.

Also, in response to federal action to terminate many near-term projects, the GRI budget has continually shifted to more near-term research. In 1984 over 75 percent of the research budget is devoted to near-term projects. Therefore, if the DOE budget does not provide funding for the continuation of long-term gas research, that research will not be adequately funded.

GRI's emphasis on near-term research has resulted in significantly increased cofunding from the manufacturing sector. Industry coordinated funding has increased from a level of $8.8 million in 1979 to approximately $31 million in 1983. However, GRI's experience with industry cofunding strongly indicates the majority of these coordinated funds will always be in areas that have the potential to be commercialized within five years. This also reemphasizes the need for DOE to provide a stable and viable funding base for necessary long-term gas-related research.



The gas industry through GRI has been totally responsive to federal policy by focusing on near-term research and increasing its total budget by 75 percent over the past four years.

3. Is the DOE budget request balanced or is it biased toward specific technologies?

To illustrate the importance of providing a balanced federal gas research program, in last month's testimony on the DOE budget, Secretary Hodel stated, "The overall goal of national energy policy is to foster an adequate supply of energy at reasonable costs. The policy recognizes that adequate supply requires flexibility in the energy system, with no undue reliance on any single source of supply." GRI agrees with this policy. However, for this policy to work and to prevent overreliance on any one energy source, DOE must provide reasonably balanced funding for competing energy technologies. An examination of the DOE FY 1985 budget request reveals that again the budget is tremendously biased in favor of electric technologies with particular emphasis on nuclear. This bias toward funding electric-related research of greater than 15 to 1 compared to funding of gas research has been evident in the DOE budget for the last ten years and conflicts with the Department's policy.

The DOE budget is not balanced and is strongly biased toward funding electric options.

4. Are there institutional barriers that limit the regulated gas industry's ability to fund R&D?

DOE's Energy Research Advisory Board (ERAB) in a report to the Deputy Secretary of Energy put these factors in proper perspective in its study Federal Energy R&D Priorities.

> A little over half our primary energy finds its way to consumers through the electric and gas utilities, and the utilities are regulated, price-controlled industries, selling their products not at free market prices, but at controlled prices well below replacement cost. . . . Both these regulated industries have weak incentives to spend on R&D. If successful, the benefits go to ratepayers; if unsuccessful, the expenditure may be disallowed as "imprudent." (Emphasis added).

DOE in its FY 1985 budget request recognized this structural problem for the electric utilities by proposing a total electric-related research budget of approximately $1,320 million. However, they totally ignored these same institutional and structural deficiencies for the regulated gas industry by proposing only $83.7 million for gas-related research. A ratio of over 15 to 1 is not sound national policy. This imbalance must be corrected by funding a viable gas-related research program.

DOE FY 1985 BUDGET REQUEST
Electric vs. Gas-Related R&D
($ Millions)

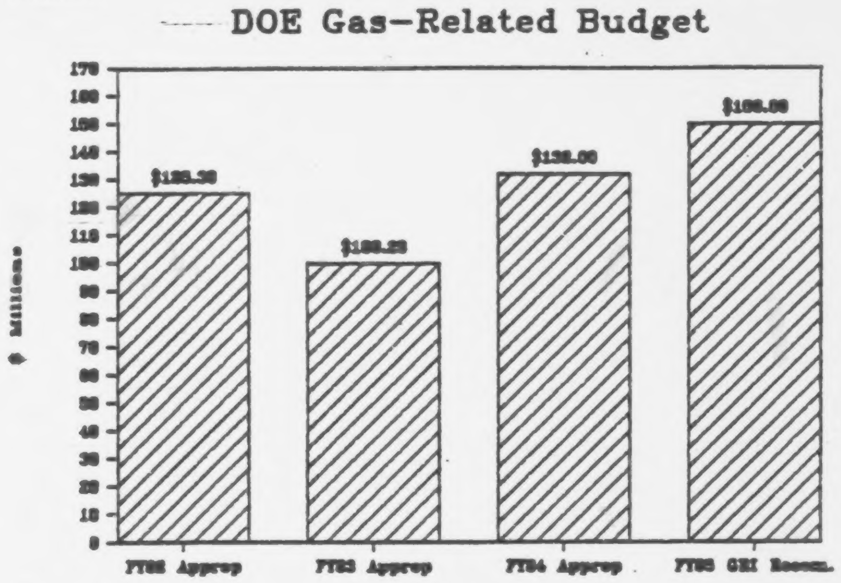
| Research and Development Program | Gas-Related | Electric-Related* |
|---|---|---|
| Magnetic Fusion | N/A | 483.10 |
| Nuclear Fission | N/A | 618.10 |
| Fossil Energy | 51.3 | 67.25 |
| Conservation | 15.9 | 5.20 |
| Solar and Other Renewables | 16.5 | 110.90 |
| Electric Energy Systems | N/A | 18.20 |
| Energy Storage Systems | N/A | 17.10 |
| TOTAL | $ 83.7 | $ 1,319.85 |

*This is a very conservative estimate of the request for electric-related research and development. No portion of the $746.1 million requested for General Sciences is included even though most of the energy-related benefits coming from this research will benefit the electric utility industry. Although most of the environment research and development funds are spent on R&D related to nuclear power, none of the $228.2 million request is included.

Regulatory constraints do create barriers that limit gas utilities' ability to fund research, but the DOE budget ignores these barriers.

**5. Are the gas industry's FY 1985 budget recommendations consistent with federal policy and congressional direction?**

The gas industry is recommending a DOE gas-related research budget in FY 1985 of $150 million. This level of funding is consistent with the budget approved by Congress for FY 1984. Also, the recommendations do not include large scale demonstration, near-term research, or commercialization activities; therefore, they are consistent with federal policy. Primary emphasis is on providing funds to continue activities already underway and previously approved by Congress.



DOE Gas-Related Budget

When you evaluate the gas industry's budget recommendations, you will find they are in the national interest, consistent with federal policy, and essentially identical to the actions taken by this subcommittee and Congress in approving the DOE FY 1984 budget.

At the end of my testimony is a table that provides details on the specific programmatic funding recommendations. However, Mr. Chairman, let me briefly mention six important long-term research recommendations that require federal support to continue joint DOE/gas industry projects.

RECOMMENDED GAS RESEARCH PROGRAMS

Consistent with the Administration's research policy, the gas industry has shifted its research program to focus its activities and funding priorities on near-term projects. Today over 75 percent of GRI's program is devoted to these near-term activities. Without an adaquate and consistent federal long-term research program, the gas industry's concentration on near-term research will leave a large void in establishing the technology base required to develop cost-effective supplemental supplies of gas and more efficient appliances and processes that use gas.

**Fossil Energy**

| ($ Millions) | FY 1983 Appropriation | FY 1984 Appropriation | FY 1985 Gas Industry Recommendation |
|---|---|---|---|
| SURFACE COAL GASIFICATION | $39 | $36.79 | $32.5 |

I remain convinced, despite the current glut of available gas and the impact of imbedded conservation measures, that the ability of the gas industry to remain a long-term competitor in the energy market depends on the validation of the coal gasification option from the standpoints of both economics and technology. GRI's current projections show an economic justification for supplementing natural gas supplies at their projected marginal costs with other sources of methane by the year 2000. In order for coal gasification to have a significant impact in that time frame, we have to validate the needed economic and design data by the early 1990s.

Of particular importance is the development of advanced processes that can use high-sulfur Eastern coals and coal fines. For several years GRI and the Department of Energy jointly supported the initial development of several advanced gasification processes. In 1981 test results and technical and economic evaluations justified our concentrating on the further development of the agglomerating ash fulidized bed process. Federal support in FY 1985 of $7 million is needed for further development of the Westinghouse process at Waltz Mill to continue PDU tests, cold-flow test facility operations, and laboratory research with an emphasis on environmental aspects.

Continued testing and operation of the pressurized ash agglomeration process at IGT is required to extend the technology to additional high-sulfur bituminous coals. A total of $6 million is recommended to continue these tests.

In addition, federal support is needed to continue basic research programs in improved catalysts, materials, components and instrumentation since significant improvements in the economies of coal gasification can result from improvements in downstream processing systems which currently comprise about one-third of the installed plant investment. A viable DOE program requires funding at levels consistent with the past two years' appropriations of $8.5 million to continue the timely development of these basic research elements of advanced coal conversion processes.

| ($ Millions) | FY 1983 Appropriation | FY 1984 Appropriation | FY 1985 Gas Industry Recommendation |
|---|---|---|---|
| UNDERGROUND COAL GASIFICATION | $6 | $6 | $6 |

Underground coal gasification offers a method for utilizing coal resources without the need for mining by gasifying the coal in place underground. As a potential source of cost-competitive pipeline-quality gas, underground coal gasification may be able to tap those vast coal deposits that would not be economically recoverable using existing or anticipated strip or deep mining methods. In comparison with surface gasification processes, underground coal gasification technology offers potential cost savings as well as possible environmental advantages through elimination of mining operations. At the present time, underground gasification must be classed as a high-risk, high-payoff technology. DOE has estimated that of the 6.4 trillion tons of domestic coal, only 450 billion tons are currently economically recoverable by existing techniques. Underground gasification could potentitally utilize about 1.8 trillion tons, producing more than 1,000 Tcf of SNG if only 10 percent of this resource is suitable for underground gasification.

It is recommended by the gas industry that $3 million be spent on the controlled, retracting injection point (CRIP) concept; $1 million be used for environmental support; and $2 million be used on an Eastern coal test.

| ($ Millions)<br>UNCONVENTIONAL | FY 1983<br>Appropriation | FY 1984<br>Appropriation | FY 1985<br>Gas Industry<br>Recommendation |
|---|---|---|---|
| NATURAL GAS | $13.9 | $13.5 | $20 |

Why should Congress approve increased funds for long-term gas supply research in FY 1985? The reason is the lack of the required technology base. As the Administration states in the FY 1984 budget request, "There appears to be adequate U.S. reserves of natural gas for several decades if conventional and unconventional gas resources can be exploited. Unconventional gas will not realize its potential unless there is additional development of the scientific and engineering knowledge for associated extraction technologies." (Emphasis added).

Within the $20 million recommendation, the gas industry urges that $4.5 million be committed to research in Eastern Devonian shales; $7 million for Western tight sands; $5 million for methane from coal seams; and $3.5 million for advanced unconventional and environmental research.

| ($ Millions)<br>FUEL CELLS | FY 1983<br>Appropriation | FY 1984<br>Appropriation | FY 1985<br>Gas Industry<br>Recommendation |
|---|---|---|---|
| Onsite | $ 4.0 | $ 5.0 | $ 6.0 |
| Molten Carbonate | 7.5 | 9.2 | 12.0 |
| Advanced Concepts | 2.5 | 2.0 | 2.0 |
|  | $14.0 | $16.2 | $20.0 |

A fuel cell is a cogeneration power plant that uses an electrochemical process to convert natural gas to hydrogen, react the hydrogen gas with oxygen from the air, and produce electricity, heat, and water. Installed onsite at a multifamily residential, commercial, or light industrial building, the fuel cell power plant can supply all of the electrical and heating requirements of the building. With changes only in the fuel-processing section, the power plant will be able to accept a variety of fuels, including all pipeline gases, gas and liquid fuels derived from coal and biomass, and a variety of petroleum products.

The gas industry and GRI have made a major commitment in funding for onsite phosphoric acid fuel cell systems (from $11.3 million in 1982 to $19.6 million in both 1983 and 1984) to offset the loss of DOE funds for near-term research. The Gas Research Institute has now totally assumed the cost of the joint DOE/GRI program to field test the 45 phosphoric acid fuel cell units.

Fuels cells are currently being manufactured, shipped, and installed in locations throughout the country to test the operational feasibility of the 40 kW power plants in an appropriate mix of actual utility environments.

The technology development program now being pursued under a joint effort with DOE and GRI is for the purpose of increasing reliability and lowering the costs of these onsite systems. On August 18, 1982, DOE initiated a four-year, $20 million program for this research with the manufacturer, United Technologies Corporation (UTC), that requires a DOE commitment of $6 million in FY 1985. The DOE work concentrates on the fuel cell stack; the fuel processing system, including catalyst research; the inverter; and specialty heat exchangers.

GRI has a parallel $6 million technology development program with UTC. Together, these joint research programs provide a solid technology base to enable the onsite fuel cell to meet the overall power plant cost, endurance, performance, and reliability goals. Also, continued long-term research by DOE is needed on advanced fuel cell concepts such as molten carbonate ($12 million) and solid oxides ($2 million).

**Conservation**

| ($ Millions) | FY 1983 Appropriation | FY 1984 Appropriation | FY 1985 Gas Industry Recommendation |
|---|---|---|---|
| GAS HEAT PUMPS | $2.0 | $3.0 | $7.0 |

As ERAB has reported, the manufacturing sector is so diverse that individual companies cannot capture the benefits of conservation R&D; therefore, the federal research role becomes critical. Specific technology-based research is needed on an advanced gas prime mover and compressor necessary to produce a competitive heat pump for residential and commercial markets by 1990. To achieve this goal requires an expanded DOE program of $7 million in FY 1985.

Several attractive long-term technologies, specifically, free-piston Stirling engines, free-piston internal combustion engines, and double-effect absorption cycles, show a good probability of providing the reliable, long-life, high-efficiency operation required of heat pump systems. Multiple programs are needed due to the relatively early stage of development. Due to the high technical risk associated with long-term heat pump options, private industry cannot fund both the near-term and the long-term development costs.

To balance the recommended DOE program, GRI is planning to spend $5 million in both 1984 and 1985 for near-term research on these programs. With over 40 million homes now being heated with gas, a high priority must be placed on developing an advanced gas-fired heat pump that offers a 50 percent increase in efficiency over state-of-the-art gas furnaces.

The gas-fired heat pump not only offers increased efficiency over existing gas-fired space-conditioning equipment but also can provide both heating and cooling in a single unit. Commercial as well as residential heat pumps could also contribute to load leveling and reduction in peak demand for both natural gas and some electric utilities, thereby reducing operating costs. The gas-fired heat pump will not be ready for commercial introduction until the 1990s at the earliest. It will provide both heating and cooling in cold climates at a lower overall cost than would otherwise be possible. In addition to development of the heat pump itself, the Stirling engine for use in the heat pump needs to be further developed. DOE's role should cover this more fundamental research at a funding level of $7 million for heat pumps with $2 million directed specifically for the Stirling engine development.

**Solar Energy**

| ($ Millions) | FY 1983 Appropriation | FY 1984 Appropriation | FY 1985 Gas Industry Recommendation |
|---|---|---|---|
| BIOMASS (GAS-RELATED) | $4 | $13 | $20 |

The production of methane from biomass is a multistep process that requires a crop be grown, harvested, transported to a central conversion facility, prepared for the conversion process, and converted to methane. Growing the crops and converting them to gas are probably the costliest steps in this process, but are also the ones most amenable to improvement through R&D. The fundamental technical need is to develop reliable integrated systems for producing methane from biomass while reducing the cost of the product.

The unique advantages of biomass make it an excellent candidate for many regions of the United States that lack conventional energy resources. To provide a model for developing biomass energy programs on a regional basis, GRI began a program with the University of Florida's Institute of Food and Agricultural Sciences in 1982. GRI has other related programs in the Northeast with the New York Gas Group and the New York State Energy Research and Development Authority and in the Southwest with Texas A&M University. All of these are cofunded efforts. We anticipate that many of the results are transferable to other parts of the country. DOE should expand the regional biomass concept by providing $4 million in the FY 1985 budget.

In terms of DOE-supported research, it should be directed in the next ten years to demonstrate at a reasonably large scale key elements of a regional biomass-to-methane system so that we have confidence in the attendant economics. This research should center on biotechnological advances that permit the manipulation of both the feedstock and the microorganisms used in the bioconversion process. Thus, using technically proven methods for cloning, infusion of genetic material into living cells, and conventional genetics, one can improve the characteristics of a plant for growth, for disease resistance, for the ability to fix nitrogen, and for a specific conversion process. One can simultaneously adapt the biological organisms of the conversion process to produce a more efficient system. With improved biomass feedstocks through bioengineering and other techniques, a cost-competitive energy system should begin to emerge.

The gas industry recommends that $12.5 million be used for biomass conversion, $1.5 million for waste conversion technology, and $2 million for research on biomass growth and harvesting.

## SUMMARY AND RECOMMENDATIONS

**A viable federal program consistent with Administration energy policy requires a budget in FY 1985 for a long-term gas research program of approximately $150 million. (See Table 1). It should be noted that this recommendation continues the programs approved by this subcommittee and Congress for gas-related research over the past two years and is approximately the same as appropriated by Congress just four months ago for the FY 1984 funding level. (See Table 2).**

### Table 1
### RECOMMENDED FY 1985 DOE GAS-RELATED RESEARCH BUDGET
### ($ Millions)

| | |
|---|---|
| ADVANCED RESEARCH & TECHNOLOGY DEVELOPMENT | $ 13.5 |
| Advanced gasification processes, fuel cells, materials and components, environmental analysis, instrumentation, coal utilization | |
| COAL GASIFICATION | 32.5 |
| Advanced concepts, pressurized fluidized bed ash agglomerating PDU, Great Plains, gasification mechanisms, coal ash studies | |
| UNDERGROUND COAL GASIFICATION | 6.0 |
| CRIP, Eastern coals, laboratory support | |
| UNCONVENTIONAL GAS | 20.0 |
| Tight sands (lenticular), Devonian shale, coal seam methane, advanced concepts | |
| FUEL CELLS | 20.0 |
| Onsite phosphoric acid technology development, molten carbonate, solid oxide | |
| EASTERN OIL SHALE GASIFICATION | 2.0 |
| CONSERVATION | 22.0 |
| Advanced gas heat pump, industrial cogeneration, desiccant systems, thermo-chemical recuperator | |
| LIQUID SPILL TEST FACILITY | 3.0 |
| BIOMASS | 20.0 |
| Growth, harvesting, conversion, waste conversion, regional programs | |
| GEOPRESSURED RESOURCES | 11.0 |
| Well data interpretation, coproduction, environmental | |
| TOTAL | $150.0 |

### Table 2
### CONGRESSIONAL APPROPRIATIONS FOR DOE GAS-RELATED RESEARCH
### ($ Millions)

| | FY 1982 | FY 1983 | FY 1984 | Gas Industry Recommendation FY 1985 |
|---|---|---|---|---|
| FOSSIL ENERGY | | | | |
| Advanced Research and Technology Development | $ 12.5 | $ 7.4 | $ 12.00 | $ 13.5 |
| Surface Coal Gasification | 53.1 | 39.0 | 36.80 | 32.5 |
| Underground Coal Gasification | 8.3 | 6.0 | 6.00 | 6.0 |
| Unconventional Gas Resources | 8.7 | 13.9 | 13.50 | 20.0 |
| Fuel Cells (Gas-Related) | 5.6 | 14.0 | 16.20 | 20.0 |
| Eastern Oil Shale Gasification | | | | 2.0 |
| LNG Safety | 6.3 | 3.5 | 3.25 | 3.0 |
| SUBTOTAL | $ 94.5 | $ 83.8 | $ 87.75 | $ 95.0 |
| GEOPRESSURED METHANE | $ 17.3 | $ 8.4 | $ 7.00 | $ 11.0 |
| BIOMASS | $ 3.0 | $ 4.0 | $ 13.00 | $ 20.0 |
| CONSERVATION | $ 10.5 | $ 4.0 | $ 24.25 | $ 22.0 |
| TOTAL | $125.3 | $100.2 | $132.00 | $150.0 |

Mr. FUQUA. Thank you very much. We will get to that as soon as Mr. Morse finishes.

Mr. Morse, we are pleased to have you here today.

Mr. MORSE. Thank you, Mr. Chairman, and members of the committee. Thank you for the opportunity to be here.

First, I want to introduce Mike Baly, vice president of government relations for AGA, who is here to keep me out of trouble.

I support the comments of my gas copanelists, and I would like to add a few comments of a more general vein which are not covered in my submitted testimony. I would like to start off with a little history.

The combination of vast reserves of natural gas found in the search for oil plus unrealistic price regulation, plus the inherent ease of using gas, provided for the rapid growth and establishment of the gas industry as a major energy contributor in this country, supplying 25 to 30 percent of the Nation's needs. This was done with a very minor reliance on the development of new technology—plenty of cheap gas; who cared about efficiency; what is the problem? Well, that has changed. Certainly, Congress knows.

The price of gas is much more realistic, but now we have the situation where not only do we not have the needed technology base to provide in this more competitive arena and also reflecting the sources of our future supply of gas, but now we also do not have the technology structure in place to make it happen. We don't have the people; we don't have the facilities; we don't have the budgets; we don't have the commitment and don't have the understanding. And that is true for the Government as well as the private sector. Right now, this is hurting us in end use.

We have a technology in place in the use of gas equipment. It is inherently a lower efficiency, because it fetters lower cost. Unless we do something, it could have effect on supply, because we now do not have the technology to effectively tap the almost unlimited domestic sources of energy in this country.

It is important that the current supply situation is not an issue as far as research goes. What we are talking about takes up to 10 to 20 years to put it in place and take it through all the steps of basic research, applied research, development, demonstration, and commercialization. So we are not talking about the bubble, the glut that we now have; we are talking about the late nineties and the year 2000.

In the supply area, in unconventional gas, the tight western sands, the tight shales more prevalent in the East, geopressured zones in the Southwest, solid fossil fuels, particularly coal, which is a resource that is spread over most of the United States, biomass, which represents an unlimited opportunity in both marine and land resources—and due to these opportunities, both ourselves and our children and their children do not have to worry about the availability of gas. It is all a matter of technology.

These resources are more than sufficient. And, again I repeat, they are domestic resources. But we all have these things; we don't have the technology in place.

Is it real for us to expect the oil industry to continue to develop our source of supply, as they have in the past, to do work on resources that are of gas interest only—only the gas industry markets? I doubt it very much.

We also have the issue that they touched on, a regulation. What is the incentive for a regulated industry to do long-term supply research 10, 20 years out? We are not able to address that issue at the moment. There is no incentive. Of course, there is the long-term aspects of it. That is what we are talking about—10 to 20 years out.

In the end use area, the residential, commercial and our industrial customers have a low technology base from the standpoint of the efficiency of the equipment they are using. We have seen very recently—because it is relatively simple to do—the dramatic increase in interest in the high-efficiency furnaces which are now dramatically taking over in the marketplace.

We need to develop the technology to make further improvements—heat pumps, fuel cells, high-efficiency cogeneration systems, and a special comment is due in the industrial area where our basic industries—steel, gas and what-have-you—are suffering from being led down the garden path of low-cost efficiency in the future. Now they suffer in competing with the world markets we are in because they have a poor energy technology to work from.

So it is very important that not only from the standpoint of costs of now competing in the world markets, we do something in the industrial arena.

Being in the research business, I have got to say something good about basic research. You have heard those general comments again and again, but we have to keep filling up that well.

Well, who are the players, and what are their roles in this game of research? Well, we basically have three. We have private industry, the gas company, and our equipment manufacturers.

Private gas companies are regulated. We already mentioned the problems they have of long-term research. So we can best do the job where we are closer to the marketplace. And where it is a short-term need to know and understand the marketplace, short-term activities, near-term, as Dave referred to them, is where we should spend our time.

We have a growing need for cooperative activities through organizations like GRI and IGT, but they are limited resources, also, and it is unrealistic to think they can carry the whole battle by themselves.

That brings us to the Federal Government. This is our strong suggestion of the increased concern with long-term issues. DOE and the Federal Government have seen fit to do—as has been pointed out for the electric industry—with the ratio of expenditure, by my calculations are close enough, 20 to 1, that there is no need to go any further.

But the analogy is there. It is an appropriate role for regulated industries for the Government to do long-term supply research, and we feel that line has already crossed in one regulated industry. We think it is appropriate in ours.

I would like to make a very brief comment about balance. You see the words in the DOE literature about the word "balance." That is the most unbalanced research program I have ever seen in my life. Anybody can look to gas research of less than 3 percent of the total expenditure, and an industry that is spending one-third and has a predominance of the resource structure, domestically, I just can't understand that use of the word "balance."

In regard to Government research strategy, we don't have one, and we can understand some of what DOE has been going through in the last several years. For whatever reason, we do not have a Government research strategy, and we need one. And I think that if it was done we could have a more effective Government research program—not necessarily an increase in dollars, which is so critical in these days.

In summary, the gas industry is in place. We are receiving 25 percent of the market. We have plenty of resources, domestic resources, from a lot of sources. If one resource tends to fall on its face, for economic or unperceived technical reasons, there are others. Gas is a product with features of cost effectiveness, of efficiency, safety and environmental. We have everything but technology.

We urge the allocation of $150 million that may be submitted by all three of us. And, looking ahead to 1986, we plan to start immediately working with DOE administration to develop appropriate long-term R&D strategy for the gas industry.

Thank you. I am willing to answer any questions.

[The prepared statement of Mr. Morse follows:]

STATEMENT OF
WILLIAM MORSE
DIRECTOR OF RESEARCH
COLUMBIA GAS SYSTEM
ON BEHALF OF THE
AMERICAN GAS ASSOCIATION
BEFORE THE
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
ON THE DEPARTMENT OF ENERGY FY 1985 RESEARCH
AND DEVELOPMENT BUDGET
MARCH 8, 1984

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## Introduction

Mr. Chairman and Members of the Subcommittee:

The American Gas Association (A.G.A.) is pleased to present this statement on the gas-related research and development (R&D) projects conducted or funded by the Department of Energy (DOE).

A.G.A. is a national trade association comprising nearly 300 natural gas distribution and transmission companies serving more than 160 million consumers in all 50 states. Collectively, these companies account for nearly 85 percent of the nation's total annual gas utility sales.

A.G.A. recommends the appropriation of $150 million for DOE gas-related R&D in FY 1985. This level of funding is justified by the long-term, high-risk nature of the projects involved, the benefits that will flow from R&D work on these projects, and the need to develop a wide variety of future energy sources.

These recommendations are the product of careful evaluation of project needs by gas industry R&D experts. Members of A.G.A.'s Advanced Technology Task Group (ATTG) -- predominantly executives who are responsible for directing research at their respective companies or organizations -- assess the merits and status of projects which are considered to be appropriate for federal funding. The projects are considered to be appropriate because they are valuable to our national interests and private investment incentives are inadequate for the commitment of large amounts of capital. Projects and technologies which the ATTG believes will require federal funding are then reviewed and approved by the A.G.A. Technology Committee. The decisions of the Technology Committee appear in this document as recommendations to your Committee. The evaluations are coordinated with the Gas Research Institute (GRI) and the Institute of Gas Technology (IGT) so that the recommendations made to this Committee regard long-term, high-risk endeavors, although research projects conducted or funded by GRI and IGT include other types of projects. These recommendations do not duplicate projects funded by GRI.

## Long-Term, High-Risk Projects

A.G.A. agrees with the Administration that the federal government should fund long-term, high-risk R&D that cannot be undertaken effectively by the private sector. Our selection process is designed to ensure that the projects for which we seek funding meet this criterion. Because they are large-scale and involve very sophisticated and novel technology, the projects frequently require 10 to 20 years to progress from the experimental to the operational stage. These long time frames discourage private sector investment because the payback on investment stretches over such a long period.

Moreover, rate regulation imposes another disincentive that discourages even the most strongly motivated companies. If a project is unsuccessful, the expenditures may be disallowed in the rate base as "imprudently" made. This shifts the expense entirely to the shareholders. On the other hand, the benefits of a successful project are enjoyed by ratepayers via reduced rates. Thus, the shareholders have a greater potential for loss than gain, so the risk related to R&D investment greatly discourages the allocation of capital to such projects. Consequently, federal funding is needed to conduct these projects.

## Need for Balanced Research

Natural gas provides space heating for 55 percent of the country's households, 40 percent of the nation's total commercial energy market, and accounts for 36 percent of the energy consumed by American industry -- a larger share than any other single energy source.

These figures demonstrate that natural gas is an integral component of our national energy supply mix. We believe that the projects included in this proposal have the potential to increase greatly our future natural gas supplies. Based on this assumption, the increased funding that we are recommending is not only advisable, but necessary to ensure America's future energy independence.

Benefits of Gas-Related R&D

Basic applied research is a fundamental requirement for developing new, gas-related technologies that will someday benefit our nation. However, research does not always lead directly to commercial results, since it is inherently exploratory. This fact inhibits extensive support by regulated gas companies. In short, such research is time-consuming (and uncertain) because it is directed toward the exploration of new possibilities rather than the simpler task of building upon developed technologies. Consequently, research entails risks and time frames that rate-regulated entities cannot easily assume.

Although the gas industry sponsors significant basic applied research, additional federal participation is necessary to maximize the acquisition of new knowledge. This should lead to the basic discoveries that can provide commercial opportunities beyond those that are easily foreseeable today.

Initiating new technologies and improving existing ones will help to ensure the long-term security of plentiful gas supplies. Most major studies by industry and government currently forecast a national energy demand growth rate of 1.3 percent to 2.0 percent per year. Even at a rate of 1.5 percent per year, this means that, by the year 2000, United States requirements for energy will grow by about 30 percent over 1982 levels. Moreover, in 1982, the

U.S. imported about 30 percent of its petroleum needs. The projected increase in energy demand, combined with our current need to import some of our energy supplies, calls for the development of domestic supplies to the fullest extent possible. The current and foreseeable supplies of domestic natural gas are plentiful, but access to these supplies must be aided by increased R&D activities.

Beyond the strategic benefits related to increased gas use, natural gas can contribute to improved air quality. Natural gas combustion emits virtually no sulfur dioxide, unlike other fossil fuels. The total natural gas system, source to end user, produces minimal undesirable atmospheric emissions and does not have significant impact upon the deterioration of our lands and waters.

## Funding Recommendations

### A. COAL GASIFICATION: $43 Million

One important technology that can augment future natural gas supplies is coal gasification. Projections indicate that coal gasification, by the year 2000, may contribute approximately 0.3 Tcf to additional gas supplies with virtually no increase in R&D support. However, vigorous R&D support indicates that coal gasification may contribute up to 1.5 Tcf to our supplies.

Western coals and eastern coals differ in their characteristics and in the mining processes used to extract them. Thus, they must be handled with technologically different gasification processes. Eastern coal produced with underground mining machines contains significantly more fines than western coal produced by surface methods. Gasification technologies that can handle these fines need to be developed.

Contemporary technologies allow significant production of gas from coal. However, to take full advantage of our coal resources, we must develop alternative gasification technologies that are more closely tailored to the type of coal to be used and that will reduce the unit cost of the end product. Several advanced technologies that are progressing toward these goals are under development; however, significant advances must be made to overcome the technical problems presented and the high costs incurred by coal gasification.

B. UNCONVENTIONAL NATURAL GAS: $33 Million

Unconventional resources, such as incremental tight sands and Devonian shales, contain extensive amounts of gas. As with coal gasification, vigorous support of R&D programs for these resources can produce very substantial additional supplies by the year 2000. That is, up to 3.0 Tcf of gas could be produced from these resources with vigorous R&D efforts, while current levels of technology would produce approximately 0.3 Tcf.

Tasks which must be completed include verifying the size and distribution of the resources; developing effective methods of overcoming the low permeabilities which typically limit flow rates from tight sands and Devonian shale reservoirs; and developing and refining methods of precisely evaluating reservoir characteristics before and after stimulation operations. Determining the size and orientation of productive reservoirs can be aided by detailed geological mapping, core analysis, and improved seismic exploration as well as other geophysical techniques.

While advances in these areas continue, there is still much work needed. Effective production of gas from tight sands and Devonian shale will require an improved understanding of the mechanisms that control the flow of gas through the formations. Devonian shales and tight sands must be fractured to improve permeability, but the technologies for exploiting formations via this method are still in their infancy.

C. CONSERVATION: $22 Million

Two examples of items in this area are cogeneration equipment and natural gas vehicles (NGVs), whose development can lead to more efficient uses of gas by consumers and, as a result, greater national reliance on domestic resources. Although these two examples are not purely long-term, high-risk, as are the other projects recommended, we believe that they are important because their immediate impact on our energy resources and air quality is so significant that they should be continued.

Cogeneration -- the simultaneous production of electricity or mechanical energy and useful heat from a single fuel input source -- captures and utilizes waste heat energy from electric power generation. Depending on site-specific factors, cogeneration can offer substantial economic benefits and total energy savings over other combinations of heat and electricity production. However, relatively high start-up costs impede the widespread use of cogeneration. Improvements in the components of prepackaged cogeneration systems will lead to reduced capital investment and, consequently, will encourage more widespread use of cogeneration.

Broad development of natural gas vehicles will serve the national interest in the transportation market, where refined crude oil products currently enjoy a virtual monopoly. The use of NGVs could also lead to improved air quality, since NGV emissions of nonmethane hydrocarbons, carbon monoxide, and nitrogen oxide are only a fraction of the emissions produced by gasoline vehicles. Furthermore, unlike gasoline vehicles, NGVs emit almost no sulfur oxides or particulate matter. Fleet use of NGVs in congested cities would provide a significant benefit in those areas in which NGVs could make the most positive difference in air quality. However, use of NGVs is currently impeded by their limited fuel storage capacity and travel range; development of increased fuel storage capability would facilitate NGV use. Most importantly, development of new storage technologies should be pursued. For example, solid adsorbent systems could increase fuel storage capacity, without requiring larger fuel cylinders, while also decreasing the required compressor output pressure.

### D. BIOMASS: $20 Million

Supplemental methane supplies from biomass and waste conversion can add significantly to total future gas supplies, since the supply of organic materials is virtually unlimited. Organic waste and biomass produced specifically for energy conversion are both viable sources of methane. Developing energy from organic waste would also provide the environmental benefit of productive use of currently "useless" materials. However, since organic waste supplies are generally not homogeneous, the uniformity of product gas quality and required pre - and post - conversion processing techniques are major concerns that currently limit the widespread use of this potential gas resource.

Biomass can also be cultivated specifically for conversion to gas and useful by-products, but farming, harvesting, and conversion technologies must be tailored to the specific feedstock. Research into all of these areas is vital to the expanded use of this most renewable gas resource.

E. FUEL CELLS: $20 Million

In a highly efficient electrochemical process, fuel cells convert the energy content of a fuel directly into electricity. For example, electrical conversion efficiency of fuel cells is approximately one-third greater than that produced by traditional generation of electricity. By combining fuel cells with cogeneration equipment, electrical and thermal conversion efficiency of 80 percent can be achieved, as opposed to only about 36-40 percent for energy delivered by a typical electric utility. Advanced concepts, to be commercially economical, require enhanced technology that focuses on using existing facilities for component evaluation, prototype endurance testing, measurement of contaminant effects, and proper electrolyte preparation in a controlled environment.

F. LIQUEFIED NATURAL GAS (LNG) SAFETY: $3 Million

The LNG resource base includes a very large worldwide gas reserve which is currently not committed to commercial use and is not expected to be committed in the near term. However, there is virtually no experimental data on the behavior of large spills of LNG. A.G.A. supports the construction of a national test site for evaluating spills of various materials, including LNG. One million dollars was appropriated in FY 1984 to begin construction of this facility; additional funds are necessary to carry the construction further. The research conducted at such a facility could simplify the safe handling of LNG and result in improved storage and tank design, thus making it easier to use LNG to supplement our gas supplies.

G. ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT: $9 Million

Advanced gasification concepts, improved materials and catalysts, and more sophisticated instrumentation can lead to significantly improved products and processes in a number of technological areas. Further research into high-temperature, high-pressure, fluidized bed coal gasification is necessary to maximize the effective use of the resource and to optimize the economic attractiveness of such ventures. Such process development would also create a need for catalysts, materials, and instrumentation capable of withstanding the hostile environment within the gasification system.

Conclusion

A.G.A. believes that our plentiful supply of gas can be supplemented by developing technologies that improve our future gas recovery capabilities. The environment can benefit from gas

[Slide 15 shown.]

use because gas is our cleanest fossil fuel. Furthermore, efficient use of gas can be encouraged by developing more sophisticated utilization technologies. However, because of the long time frames required to make these technologies operational, R&D projects must continue uninterrupted and must be funded at a level that allows full exploration of technological possibilities. The projects A.G.A. recommends for federal support can provide substantial supply, utilization, and environmental benefits.

Mr. FUQUA. Thank you very much, Mr. Morse.

In looking at your statement, you are speaking in behalf of the American Gas Association.

Mr. MORSE. Yes, sir.

Mr. FUQUA. I did not make that clear when I first introduced you, and I apologize for that omission.

Bernie, what is the total amount of annual funding that IGT receives from DOE?

Mr. LEE. In 1983, it was $4 million-plus. A little over $4 million.

Mr. FUQUA. And what would your recommendations be at this time total, the part that IGT would receive?

Mr. LEE. We are not that presumptuous to assume that everything that we are looking for would ever come down. I think what we are saying is where there are parts of the $150 million program that IGT could play a role. There are critical programs we would like to see move forward. And I have no idea—we have a capability of doing a lot more work than we have been. So we would like to see us move up, and certainly we can do work in the $10 million class for the Federal Government very effectively, in addition to serving our industrial clients.

We have in the past conducted research for the Government to the tune of $25 million. So the amount of work done needs to be looked at by Congress. But I think, as I said many times, to do effective research you need to have a steady support base in order to build the necessary team and conduct research on a planned basis rather than rushing around from one fiscal year to the next, which is extremely counterproductive.

Mr. FUQUA. You are requesting some $6 million for the U-GAS——

Mr. LEE. Yes.

Mr. FUQUA [continuing]. Process. And is that already being used by the Memphis gasification project that SFC is funding?

Mr. LEE. No. That is right. That is the same process being used in the Memphis application to the SFC, and the application there is to convert bituminous coal to industrial fuel gas in the Memphis area. And negotiations are going on, and we are hopeful that it will go forward.

What we are saying here, Mr. Chairman, is to extend that technology to cover all types of U.S. coal, and in particular to carry it to the point of higher pressure that will allow that advanced technology to be applied to many other areas besides industrial fuel; and I mention examples of chemical feedstock, natural gas, more efficient power generation. And all these things require higher pressure operations.

In the system that we have at IGT, which was built with our own funds we are contributing to the project, is a system that could run at 500 pounds per square inch range. We are looking for support to allow that equipment to be applied to a wide range of U.S. coals.

Mr. FUQUA. Are the French contributing to part of that process, too?

Mr. LEE. No, sir. That is a different item. The French project is a totally different entity. They are also interested in our technology, but French coals are quite different from American coals. They don't have the rich seams that we have here, so they have a lot more rocks and roof and floor material. The American coal is, relatively speaking, much easier, much more uniform.

So the French will be interested in applying this to mostly French coal, and we like to apply this technology to American coals, that broad spectrum, from the lignites to bituminous and subbituminous coals.

Mr. FUQUA. Dave, Assistant Secretary Vaughan testified yesterday and indicated they were planning for—to enter into negotiations for the commercialization of the onsite phosphoric acid.

Are you people involved in that in any way? Have you entered into any, do you plan to be, or have they made any preliminary discussions with you about being involved in that?

Mr. WEBB. Mr. Chairman, yes. What we have with the Department of Energy in fuel cells, we have two joint programs. One is field test the 40 kW units which we are totally funding. That is a near-term effort. We agreed as our obligation as a gas industry to totally fund the field testing of 45 units. The subsequent program we have with DOE is to do the technology development, to bring down the cost, improve the reliability, hopefully reduce the complexity of the manufacturing process. That, we are cofunding on a one-to-one basis.

My understanding of the DOE budget is they have only requested approximately $1.5 million to budget for that effort. To meet the planned current program as called for in the contract would require $6 million from GRI and DOE. We have our $6 million pledged toward that, Mr. Chairman.

The actual commercialization activity they are talking about, I am not sure, unless they are talking about the field test; and the field test is not the commercialization activity. The commercialization activity in the phosphoric acid fuel cell program, if we can get DOE funding continued for the technology development work, is probably a 1987–88 timeframe, and I would envision that it would be a gas industry to the manufacturer program where the manufacturer would make a commercial offering to the utilities and then the utilities would have to place orders based on their own market studies and the amount of demand that is in their market.

Mr. FUQUA. Out of the list of recommendations that you made, Dave, what do you consider probably the top two or three priorities?

Mr. **Webb**. It would seem the top two or three would be, in the coal gasification program we should do more than just fund the work that is ongoing at the Department's own labs. We ought to put another $15 million or $20 million in coal gas to continue the industrial process underway.

I definitely think that in the fuel cell program there ought to be funds in there to continue the contractual commitments with the gas industry in the onsite fuel cell program.

I think they should place emphasis in the conservation program on doing the basic research needed for heat pumps, recuperators, several systems, cogeneration, because a lot of that research is being mislabeled as near-term. We are talking about basic research on engines and compressors that may be 10 or 15 years from the marketplace.

Mr. **Fuqua**. Mr. Morse, when do you think the so-called gas bubble is going to burst? Maybe you would like to know that, too. When are increased domestic gas resources going to be needed?

Mr. **Morse**. That is a tough one. I don't think there's any hard numbers out there. I don't think there are any hard numbers out there which everyone would stand up and salute. But I am sure early in the 1900's, if not before, you are going to start to see the effect of that because you start to see the posturing and what-have-you.

Mr. **Fuqua**. 2000? You said 1900, I thought.

Mr. **Morse**. I meant 1990. Excuse me.

Mr. **Fuqua**. OK.

Mr. **Morse**. Thank you for the correction.

I would expect to see it before 1990. And Mike probably is in a position to answer more on that.

Mr. **Baly**. Mr. Chairman, this excess deliverability that we have right now of around 3 trillion cubic feet on an analyzed basis we think would probably last another 2 to 4 years. The demand has been down due to the recession, due to the economy, lower than normal weather. Gas sales last year were 17 trillion cubic feet compared to normally 20. They are up the first 6 months. It looks like for this year they will be up about close to a trillion cubic feet.

But just to give an example of the need for supplementals, I think supplementals this year will be about 6 percent of total gas supply. By the year 2000, we would anticipate about 30 percent of the total gas supply would need to be supplementals.

Mr. **Fuqua**. Mr. Morse, assuming in the early 1990's, what do you think is going to be first on the line available to us for this?

Mr. **Morse**. I believe first on the line would be the unconventional natural gas, the tight western sands, gas from coal seams.

Mr. **Fuqua**. Do you think those are the technologies that are nearest ready for commercialization?

Mr. **Morse**. A combination of technology plus economics. Following behind that, I would say——

Mr. **Fuqua**. But when the bubble bursts, prices will get a lot more competitive for new technologies?

Mr. **Morse**. Yes, sir, depending how fast the bubble bursts versus the availability of gas, and the price reacts accordingly, also. And the trouble is, when it hits the fan it's too late as far as new technologies.

Mr. **Fuqua**. You can underline that, too.

Mr. **Morse**. My own company thinks nothing of giving you a scientific problem 6 months to 1 year before they need it.

Mr. **Fuqua**. Mr. Boucher.

Mr. **Boucher**. Thank you, Mr. Chairman.

I want to commend the witnesses on their testimony today.

Mr. Morse, I was very interested in your prepared testimony, the mention of a natural gas-fired car.

Could you give us some indication of what the status of the development of that vehicle is and what its ultimate cost and perhaps what some of its physical characteristics would be?

Mr. **Morse**. Well, there is a lot of difference of opinions within the gas industry where that stands. As you know, in Italy for years they have been running hundreds of thousands of cars on natural gas. New Zealand is going big in that way. Canada is going over dramatically to it because of the very aggressive tax and price structure situation they have set up.

In this country, a number of companies are trying to actively pursue it, and the approach they have been taking is dual fuel, where you run the car on both flipping the switch—you run on gasoline and natural gas, and as a retrofit you add the natural gas. This has several deficiencies. One is the adding of retrofit in secondary fuel system is very expensive as opposed to being done in a plant on a mass-production basis.

Also, being able to run the same engine on both fuels radically cuts back on the performance of the vehicle. We could have dedicated vehicles. We could dramatically improve the performance of the cars 25 percent.

So we are sort of goat, chicken, and eggs situation. You are not going to get dedicated vehicles until the refueling structure is in place; the gasoline stations you might call. On the other hand, people aren't going to put their gasoline stations in until they are convinced that the system is going to work.

From a standpoint of maintenance, the environment, natural gas, in terms of performance, of course, it is very close. But we have some—we have got to overcome this problem of dual fuel, and we have some technical problems to resolve. We have to come up with better storage systems. Using old, heavy classical steel cylinders for a lot of reasons engineering wise, weightwise, is not appropriate.

We have got some work that has to be done, but if properly addressed, and putting our shoulder to the wheel, there is no reason why natural gas can't be supplying a significant increase of the fuel for transportation. It's already been done in other countries.

Mr. **Boucher**. Is there any effort being made by anyone in the United States today to commercialize a natural gas-powered automobile?

Mr. **Morse**. Yes, sir. Ford is very active. Several supply companies are trying to sell a retrofit and conversion equipment. Alcoa is active. Various gas companies are active.

We are throwing a little too much money and effort at the problem versus the potential. We tried to get a major program through GRI, but we ran into problems at FERC. For some reason, they can't understand why GRI should be doing transportation fuel research. So that has set us back, and now we have to approach it from a different direction.

Mr. BOUCHER. Is there Government funding being provided solely for that research? I wasn't sure I understand.

Mr. MORSE. Very little. Nowhere near what is available or should be available.

Mr. BOUCHER. Do you foresee a time, and would you care to project a timeframe when we might have vehicles generally in use in the United States which are either totally or partially powered by natural gas?

Mr. MORSE. I guess the easy flip answer would be to say, if you can tell me what is going to happen in the Middle East, I will tell you what is going to happen in CNG vehicles.

I can see within a 5-year period if the gas industry is more aggressive and resolves some of these technology issues which are essentially short-term issues, there is no reason why they can't. Certainly, with dual fuel, it is possible right now, except it makes economics more difficult. But 5 to 10 years from now there is no reason why they can't be a rather significant impact.

Mr. BOUCHER. Thank you very much.

Legislation has been introduced by Congressman Rahall in West Virginia and also by Congressman Walgren from Pennsylvania which would establish a 5-year plan for fossil fuel research and development. I'm not sure that included in that legislation is coal gasification or coal liquefaction, both of which you have some interest in.

Assuming the projects in which you have an interest could be included, would you generally support legislation that would direct the Department of Energy's research efforts over a longer period of time?

Mr. MORSE. Yes.

Mr. BOUCHER. Would others on the panel care to comment on that, perhaps point out some of the attributes that that legislation would have?

Mr. WEBB. Yes, sir.

The Gas Research Institute would certainly support something that would set up a longer planning horizon because what we have tried to do is pick up the near-term research as DOE dropped it under the assumption they would continue the basic long-term research.

The only other thing I would encourage in any sort of legislation like that, I think you're making a mistake if you don't insist that there is industrial cofunding in the research. I think you will end up with the research being performed, more dollars thrown at a problem, performed only in the national laboratories and mostly internal in the Energy Department's own research centers, and there still would not be a way to transfer the technology to industry or for any industry to have enough proprietary experience to know which of the processes truly make sense from an economic standpoint.

I would encourage—there should be a mechanism so industry is involved in planning the projects and has some commitment so there is a way to get it to the marketplace.

Mr. BOUCHER. Dr. Lee.

Mr. LEE. As I was a performer of R&D, I would certainly like to have that opportunity of planning a more orderly and definite program than year-to-year continuation. I think we would welcome that opportunity and make our case known to satisfactorily see something done. That example I know has been in use in Europe where they plan longer horizons. And we used to do that for a while in many programs. But nowadays it's a smaller scale work and a shorter horizon, and it's probably even more difficult when you work on small basic R&D to cut it off after 1 year. More emphasis is required for longer range planning.

Mr. BOUCHER. We had a panel of witnesses 2 days ago who spoke with regard to—specifically to coal research and development, and their statement generally is that greater utilization of coal is perhaps one of the best paths that we can pursue in terms of achieving energy independence nationally. I suspect that you would say that paralleling that effort a greater utilization of natural gas can help us achieve that goal.

Both of these fuels fall within the category of fossil fuels. And in looking at the Department of Energy's request for fiscal year 1985, we see that their nuclear research and development requests are more than double the fossil fuel requests.

One of the witnesses on Tuesday suggested that we simply reverse those budgets and that the country might be far better off if we did that.

I would be interested to hear what each of you thinks concerning a research and development request for nuclear R&D that is more than twice that for fossil fuels.

Mr. Morse, would you like to start?

Mr. MORSE. I'm trying to think of something nice to say. I think you will know where I come down and the bottom line after I get through. I think it's a matter of looking at the resources we have available to us, looking at the economics, the issues of national security, and what-have-you.

The issues that Congress has to consider—and in no way can the present proposals, the existing program or proposed program be considered a balanced program. Let's face it; the Department of Energy—the AEC is still with us, and I do not wish to be negative about what is a growing energy source in this country. Use of nuclear energy continues to increase. And from the long term, conceptually I personally have no problem with that.

My problem is the allocation of resources, allocation of financial resources to match the potential of the natural resources, and that is where I do not see 2 percent going to those vast amounts of natural resources which can be gas or converted to gas right now.

Mr. BOUCHER. Mr. Webb.

Mr. WEBB. Yes, Mr. Boucher. I certainly would support a more balanced program. I would be a little concerned about trying to determine—let me start back over.

Yes, I think there is imbalance. There definitely should be more money allocated to fossil energy research. Even the Department's own projections indicate over 80 percent of our energy in the year 2000 is going to come from fossil energy resources.

The difference in the funding level is too great, but I am not sure that you can reverse them and make sense either, because it costs more to convert to produce electricity than it does to produce gas or oil or mine coal. So there is a difference in the fundamental way that one is a conversion process and the other is a primarily extraction process.

Mr. **Boucher**. Dr. Lee.

Mr. **Lee**. I think that there is a philosophic point one must accept that seems parodoxical. There seems to be no quarrel doing nuclear work. I wouldn't be here with my Ph.D. if it wasn't for the nuclear program. However, what seems to be accepted is that R&D in the nuclear field, even though the nuclear industry is mature—the mining of uranium, the processing of uranium, is all known technology that can go on without any particular concern about the balance with other forms of R&D support; whereas, a nonnuclear aspect, the tendency seems to be to leave that to the so-called private sector to handle it all.

I think that philosophy needs to be called to a better balance that every technology, every energy option, has a longer term alternative that needs to be looked at. If you take that into account, you can automatically come to a balance, fossil or nonfossil.

Mr. **Boucher**. Thank you very much for those comments.

What I hear all three of you saying is that we need a greater commitment to funding fossil fuel research and development. The legislation that Congressmen Rahall and Walgren have proposed would provide for about $750 million in additional funding for fossil fuel research and development over a 5-year period.

In your opinion, can we use any—appropriate those dollars, those extra dollars, for work that will lead toward enhancing energy independence for the country?

Mr. **Lee**. I would totally endorse that with a well-planned program that doesn't shovel money out, because I think a dollar spent on energy R&D results in long-term benefits to the Nation that far exceeds the value of the cost of the dollar spent at the point it's spent.

Mr. **Boucher**. Mr. Webb.

Mr. **Webb**. Yes, sir. I think that you could reasonably spend $700 million over 5 years additional on fossil energy research.

Mr. **Boucher**. Mr. Morse.

Mr. **Morse**. I think there is no question about it.

Mr. **Boucher**. Thank you very much.

Thank you, Mr. Chairman.

Mr. **Durbin**. I would like to ask what might be a loaded question. Is there any resistance among your members to the development of synthetic sources for gas in the future, keeping in mind those that presently have domestic sources? Did you have any resistance within your association to looking to new sources which might not involve the well heads that they presently own?

Mr. **Morse**. No. There is no philosophical difference or conflict of interest, or however you want to call it. I think the negative thinking toward coal gasification at this moment—it is now on the downswing again, and, like conversion of coal to liquids, it keeps going through these cycles. I think there is a reflection of the near-term situation, unfortunately, of the availability of gas at the price we see it now being available at versus what we see the price of gas from coal. And short term, the price of gas from conventional sources is going to be cheaper than the price of gas from coal.

Also, I think in the eyes of top management there is a real fear about seeing what is happening to the nuclear plants, for the same thing happening to us in coal gasification plants.

The capitalization or the cost of these facilities are so huge compared to the size of these companies that if something goes wrong, especially in regulatory issues, of which companies have no control, it can bankrupt the company. And you see examples of what's happening in the electric side of it.

Well, the same thing could happen to us if we jumped into coal gasification, for whatever reason—the need, the price—and these are long-term projects that take 10 years from when you start to get these $3 billion plants in existence. And compared to the capitalization of our corporations, that is a huge investment, huge decision. So I think the combination of those two things is where you might get some negative sounds.

I don't know of anyone that feels that coal gasification might conflict with our production activities.

Mr. DURBIN. Let me ask you an example of one particular company that affects my area. Trunkline Panhandle Eastern, where they have made substantial investment in liquefied natural gas from Algeria through a subsidiary. I believe they have invested about $1 billion both in the conversion facilities and the tankers to move the liquefied natural gas. They have made a massive investment in the future of importing a liquefied gas from a foreign country, which seems to carry some risk.

Do you see the same—is that evidence of any reluctance on their part to consider coal gas and its risk? It seems to me like they have gone way out on the limb in committing themselves to that.

Does the industry reflect that kind of attitude?

Mr. MORSE. I can't speak for Panhandle, but expect we have the same problem. We have a half a billion dollar plant sitting in Maryland an hour or two away from here that is an unused LNG plant. So I understand what you are saying about Panhandle, who is a supplier to the Columbia Gas System.

But the concern for huge capital upfront investment and the ability to recover the costs, whether it is LNG or my earlier remarks about coal gasification, after we have seen what is happening to nuclear activity, is a very major concern of utilities. You realize if we are wrong, the corporation could go down the tubes. If we are right, we are still a regulated industry and we don't recapture the glory, say, that a private corporation can have if they take a very high risk and are very successful.

Mr. DURBIN. I guess what it boils down to is if they are prepared to make a major capital investment for a foreign source of gas, as an example that I used, are they equally prepared to make that same kind of commitment to a domestic energy source like conversion of our high sulfur coal in central Illinois and West Virginia and Virginia around the country, for a future source of coal gasification?

Mr. MORSE. Well, there is one thing about LNG that is different than coal gasification or biomass or some of the unconventional activities. At the moment that decision was made, there was not a technical risk. There was no doubt an LNG plant could be designed and built and perform exactly as designed and come in at cost. That is not a guarantee in regard to coal gasification or biomass or the other activity. That is not an established technology.

So on top of the capital cost risk, you have this inherent technical risk. And even if you can get the management of corporations to see beyond that, the bankers are a little more reluctant.

Mr. **Durbin**. Do you feel in your industry that there is a movement abroad for sources as being a safer technological investment rather than feeling that they want to invest in a domestic source?

Mr. **Morse**. No; definitely not. The other way. They are looking basically at the experience of the LNG. We have the resources within the country, and I think that is where the intention is.

Mr. **Durbin**. Thank you.

Dr. Lee, one of the topics that we have discussed I guess in Congress, even before I arrived, and while I have been here, quite frequently is the question of acid rain.

What are you doing at IGT? What do you feel you're moving on that might give us some sort of promise or hope in the future to use high sulfur coal in a responsible way?

Mr. **Lee**. There are two ways to attack acid rain. One is to remove the pollutants after the combustion process, which is the current emphasis; and the other approach is to clean up the fuel before you go through the combustion process.

Personally, I have been a strong proponent of cleaning up the fuel, because it is so much smaller in volume. You can remove all the sulfur in the fuel cleaning process so that the combustion products can be sent to the atmosphere, whatever the environmental regulations might be. Cleaning up the tail gas is an incremental solution.

Mr. **Durbin**. Is that the scrubber?

Mr. **Lee**. Yes, sir.

Any time after the combustion, you have scrubbers, dry, wet, various kinds. I understand the dilemma today. People that have a plant want to do what they can to overcome the immediate hurdle. So I think we ought to treat that much like we treat gas guzzlers. You can't stop people from driving gas guzzlers, but what you do is create an atmosphere such that, in time, the gas guzzlers get older and get washed out of the market and, presumably, the more efficient cars come to market.

I feel the same type of environment can be created to encourage the total solution of potential gas cleanup, potential acid rain removal, by cleaning up the fuel in the front end. That requires cleaning up the fuel gas, remove all the pollutants, and burning clean fuel gas, which is very easy to handle in a more efficient way.

Mr. **Durbin**. What are the economics in the current technology? You're cleaning up the fuel versus the current scrubber technology.

Mr. **Lee**. From what I have read, obviously the biggest market you are addressing is the electric power generation sector. Today's available technology for converting coal to clean gas and then burning that in combined cycle-powered generation plants can be built at equal or slightly less dollars per kilowatt than a steam plant with a latest scrubber afterward. So I think today if you were to build a new plant, the technology for cleaning the fuel up is there already.

Mr. **Durbin**. Is there evidence that the industry is turning in that direction, moving toward cleaning up the fuel?

Mr. **Lee**. I like to think so. The project on the west coast, the Cool Water project, is a demonstration.

There is much more in the natural gas field, a lot of cogeneration work which is in the same way except you are using a well known technology. The trend will be there.

We need a legislative framework to encourage people to look at that. Replacing old facilities with new ones, new technology, will be allowed to come in instead of encouraging the next incremental improvement.

Mr. **Durbin**. The big question we have to ask ourselves politically is whether we will have time to wait for those gas guzzlers to become obsolete and be replaced with new ones.

Mr. **Lee**. That is true. But whatever has happened in the past few years, we notice that happening already, fewer and fewer larger cars are on the market but if the environment is not correct, then people will be encouraged to buy bigger cars and you go back to the offswing. Proper climate is most important.

Mr. **Fuqua**. Thank you very much, gentlemen. We appreciate your being with us here today and sharing with us your observations about fossil fuel.

Next panel, Mr. John Robert Friday, vice president, research and development, Lummus Crest; Mr. Frank C. Schora, president, Hycrude in Chicago; Mr. Joseph A. McElwain, chairman of the board, Montana Power Co.; and Mr. S.R. Hart, Jr., vice president, research and development, Southern Company Services, Inc.

Your statements will be made a part of the record.

## STATEMENTS OF JOHN ROBERT FRIDAY, VICE PRESIDENT, RESEARCH AND DEVELOPMENT, LUMMUS CREST; FRANK C. SCHORA, PRESIDENT, HYCRUDE; JOSEPH A. McELWAIN, CHAIRMAN OF THE BOARD, MONTANA POWER CO.; S.R. HART, JR., VICE PRESIDENT, RESEARCH AND DEVELOPMENT, SOUTHERN COMPANY SERVICES, INC.

Mr. **Friday**. Since my statement is part of the record, I will summarize my testimony which you have a copy of.

I am here to support the continuation of coal liquefaction research as a part of the DOE fossil fuels approach, and to support the expansion of that program to a more reasonable level, and to a level which would enhance the status of coal liquefaction technology.

I am sure you are all aware that coal liquefaction technology development today is nearly dead. There is very little going on in the industrial research laboratories toward coal liquefaction primarily because of the uncertainty in when the technology will be required. There is little doubt that it will be required. Meanwhile, the Department of Energy has chosen to phase down coal liquefaction research to a very low level and proposes for 1985 to do only laboratory scale work.

We believe that that is an ineffective way to promote the technology, because coal liquefaction requires integrated operation of pilot plants in order to move the technology forward.

A word about Lummus Crest. We are a project management, design, construction engineering operations and maintenance company worldwide.

We primarily work in the petroleum, petrochemical, chemical and related process industries. We have long held a strong posture in research and development in those areas, and for the past 4 years have been involved in two Department of Energy contracts directed toward improving coal liquefaction technology.

We particularly pioneered the application of integrated coal liquefaction processing to coals and have achieved very high hydrogen efficiency and good product quality as a result of that work.

We believe that that work has redirected coal liquefaction technology in the United States. Our concepts have been used in other peoples' facilities, including that at Wilsonville, AL. They have adopted the equipment there to pursue the concepts which we have pioneered, and with very good results.

We propose that the integrated coal liquefaction processing technology be supported on an integrated basis, that a lab scale research program is inadequate to move that technology forward, and that a program involving something on the order of $5 million a year for at least 1985 and 1986 be adopted, authorized for the Department of Energy's fossil fuel budget, and with that, we can make substantial improvements in the process, especially the expensive reaction sections, and that we can further test additional coals in the two-stage process.

That is the summary of my testimony. I will be happy to answer questions.

[The prepared statement of Mr. Friday follows:]

# LUMMUS CREST, INC.

# INTEGRATED TWO STAGE COAL LIQUEFACTION
# DEVELOPMENT PROGRAM

MARCH 1984

## INTRODUCTION

Mr. Chairman and members of the subcommittee, I am Bob Friday, Vice President of the Engineering Development Center of Lummus Crest, Inc. Execution of our current Department of Energy Contract (DE-AC22-82PC50021) for the Integrated Two Stage Liquefaction (ITSL) development program is my responsibility. On behalf of Lummus Crest, a wholly owned subsidiary of Combustion Engineering Inc., we thank the subcommittee for the opportunity to testify at this hearing on the Department of Energy's proposed FY 85 funding of fossil energy research and development in coal liquefaction. We are particularly concerned about the Administration's intentions to confine this research to purely bench-scale efforts, which would result in the termination of operations of Lummus Crest's pilot plant unit in New Brunswick, New Jersey.

## LUMMUS CREST

Lummus Crest is an international organization providing project management, engineering, procurement, construction, start-up assistance, plant operation, maintenance and training for petroleum, chemical, petrochemical, pharmaceutical, metallurgical and other process industries. We are the managing contractor for the nation's first commercial synthetic fuels plant, the Great Plains Coal Gasification Project in North Dakota, for which construction is nearing completion.

Moreover, Lummus Crest maintains a strong R&D capability for developing new and improved processes and optimizing existing ones. (See Attachment #1) Over the years, Lummus Crest has become a recognized leader in coal liquefaction technology, beginning in 1971 with its proprietary one-step direct coal liquefaction process.

## LUMMUS CREST AND ITSL

In 1980, Lummus Crest and DOE began pioneering efforts in the development of the Integrated Two Stage Liquefaction (ITSL) process. ITSL consists of three parts. First stage thermal reaction for coal dissolution is followed by separation of solids via deashing. Deashed first stage residual product is then converted to high quality distillate products in the catalytic second reaction stage. The term integrated refers to the interdependency of the two reaction stages. Second stage hydrogenated byproduct is used as first stage solvent, resulting in a rapid and efficient coal dissolution.

In 1979, Lummus Crest built a 1/4 ton per day pilot plant at its New Brunswick laboratories for the sole purpose of demonstrating the ITSL process. Work under a two year 10.5 million dollar DOE contract showed that ITSL held the promise of yielding more liquid product of higher quality and demonstrated a vastly improved hydrogen consumption selectivity than had been previously achieved with single stage processes.

Based on the promising results of the first contract, DOE in 1982 awarded Lummus Crest a follow-on $10.3 million contract of which $8.7 million was DOE money with cost sharing by Lummus Crest and Cities Service Research and Development Company of $1.5 million and $0.1 million, respectively. This contract ends June 30, 1984. The operation of the 1/4-ton per day New Brunswick pilot plant focused on expanding the applicability of ITSL to Wyodak sub-bituminous coal and to study various process improvements with a bituminous Illinois No. 6 coal. At the end of 1982, the experimental coal liquefaction facility at Wilsonville, Alabama was adapted for ITSL operation. Lummus Crest personnel assisted Wilsonville pilot plant personnel during their initial ITSL run (see Attachment #2). Since that initial ITSL run, the Wilsonville pilot plant has operated exclusively in the ITSL mode, while achieving the same successful results as had been previously attained at New Brunswick.

## WHY SHOULD ITSL DEVELOPMENT WORK CONTINUE NOW?

We recognize that, in these times of budgetary limitations, it is incumbent upon us to explain why continuation of this type of work at our New Brunswick ITSL pilot plant is technically justified and why this particular pilot plant should be funded. Lummus Crest believes that it is in the national interest to have the use of efficient direct coal liquefaction technology at the time it becomes the most economical source of essential liquid fuels.

Considerable progress has been made in the development of the ITSL process, but abandonment of pilot plant work now would likely force future development efforts to be conducted under crisis conditions without the special insights of the currently involved scientific personnel. Therefore, a low cost effort must be continued in order to maintain the achievements obtained to date.

## WHY SHOULD NEW BRUNSWICK PILOT PLANT OPERATION CONTINUE?

The National Energy Policy Plan states that "Proof of Concept is where enough is learned to establish the technical viability and basic engineering feasibility of a concept and to forecast its expected economic and environmental performance standards, permitting industry to make decisions concerning whether the concept merits further development".(1)

(1) DOE/S-0014/1, October 1983, p. 14

The 1/4-ton per day pilot plant in New Brunswick is the smallest scale at which Proof of Concept of the Integrated Two-Stage Liquefaction Process (ITSL) can be established. ITSL consists of two separate reactions, deashing, and several recycle operations, all of which must be operated co-currently in order to generate the steady-state results that are required for engineering evaluation of the process. The integrated pilot plant investigates a wide range of conditions for one or more different parts of the process and can quantify the effects of these conditions on overall process performance. On the other hand, bench-scale research is limited to isolated investigations of component parts of a process, making it very difficult for industry to interpret the impact on the whole process of these unsteady state investigations. The development of this process would, in fact, be stopped completely if only segmentalized bench-scale research using model compounds were substituted for New Brunswick pilot plant operation. In fact, the bench scale research programs in support of ITSL obtain their starting materials (intermediate streams, products, catalysts, etc.) from New Brunswick operation which is large enough to generate samples for testing.

Lummus Crest and DOE were the pioneers in ITSL development. Lummus Crest will continue to improve the ITSL process because of our pilot plant's flexibility, short turn-around time for modifications, and our unique multi-train second stage reaction system. Our pilot plant is large enough to generate steady state proof of concept data, while producing the samples required for more fundamental university and private industry research investigations.

In addition, considerable equipment that is not part of the New Brunswick pilot plant has been used to investigate variations of the process, thereby adding to the data base and understanding of ITSL. The equipment includes autoclave reactors, coker, and expanded bed hydrotreating reactors of three different capacities. These ancillary units enable Lummus Crest to carry out its own small scale tests in support of the pilot plant, and our ability to coordinate pilot plant and bench-scale investigations has contributed to the rapid development of ITSL.

Lummus Crest, Inc.'s performance during DOE contracts has been (to quote DOE officials - see Attachment #3) "...highly professional and proficient" and "...would recommend Lummus without hesitation for future awards".

Lummus Crest, Inc. is committed to the ITSL technology as evidenced by our 15% cost sharing participation during the current DOE contract. Lummus Crest is willing to continue this cost sharing arrangement for an additional DOE contract. As a result, the cost to the government of continuing the Lummus Crest ITSL development program is $5 million per year.

## ACCOMPLISHMENTS TO DATE OF LUMMUS CREST ITSL DEVELOPMENT PROGRAM

The results generated by the two DOE contracts have changed the direction of coal liquefaction technology in the United States. ITSL is now considered by the DOE and private sector organizations as the coal liquefaction process most likely to be commercialized. Funding for the earlier processes, such as H-Coal, SRC-I and SRC-II, has ceased and the success of ITSL has encouraged other companies to modify their processes in an attempt to take advantage of the two-stage concept. Several other DOE contractors have had their programs redirected so as to support the Lummus ITSL development, with Lummus supplying them with products, intermediate streams, catalysts, etc. as starting materials for their investigations. These organizations include the Pittsburgh Energy Technology Center, Sandia National Laboratories, Batelle Pacific Northwest Laboratories, Conoco Coal Development Company, Chevron Research Company, and Pittsburgh and Midway Coal Mining Company.

The pilot plant program in New Brunswick has concentrated on establishing the technical advantages of ITSL, which have now been demonstrated with Indiana, Illinois and Wyoming coals. The major accomplishments to date are listed below:

1. Greater yields of distillate products - 15-20 percent higher than achieved by the best of the earlier generation of liquefaction processes.

2. Higher quality liquid products, which makes them easier to incorporate into refinery operations. Chevron Research is currently testing ITSL products in bench scale units, using commercial refinery technology and the results support this claim.

3. Hydrogen consumption selectivity is much improved over other processes, resulting in more synthetic liquids production for a fixed consumption of expensive hydrogen.

4. The ITSL products have been shown to exhibit lower toxicological activity than any other coal-derived liquids. It is quite likely that small changes in ITSL process conditions can reduce the toxicity of the product liquids to the degree that they are comparable to petroleum streams. Additionally, the in-plant intermediate streams are also less biologically active than in other liquefaction processes. This will make the plant safer for plant personnel and simplify waste disposal.

## PROPOSED SCOPE OF WORK FOR CONTINUED LUMMUS CREST ITSL PROGRAM

ITSL has been established as the most efficient direct liquefaction technology. While considerable progress has been made under previous contracts, further proof of concept type work is needed to bring this promising technology to a state of sufficient readiness so that, when needed, commercialization efforts could proceed in an orderly and economical manner. Therefore, the work proposed is a necessary and logical continuation of the past ITSL development program and is in the national security interest.

### Program Objectives

Specifically, Lummus Crest proposes a two year program to follow the current contract and to achieve the following objectives:

1. Investigate process modifications in the New Brunswick pilot plant which will result in significant cost reductions for a commercial ITSL facility. These modifications, which were explored in non-integrated smaller scale work at Lummus Crest, would mainly target

reduction in the second stage reaction system volume which is known to be the most expensive part of the ITSL process. A reduction in the size of this section could reduce a 30,000 T/D commercial plant investment by $300 million or more. No current or planned research program would have as great an impact on coal liquefaction economics as such a capital reduction. The investigation of low pressure first stage operation begun under the current contract would be continued as this would also reduce capital and operating costs.

2. Extend the ITSL technology to a broader variety of U.S. coals such as those from Kentucky, West Virginia and Utah.

## Program Cost

Lummus Crest estimates the Department of Energy's contribution for continuing the ITSL development program at approximately five million dollars per year. To demonstrate Lummus Crest's commitment to the ITSL technology, we are willing to add our contribution to the ITSL program in a manner similar to our current contractual agreement.

## CONCLUSION

The 1983 National Energy Policy Plan states, "The same changes that have led to revised energy projections have resulted in currently diminished incentives for private investment in synthetic fuels. In these circumstances, some continued federal support for synthetic fuels development is warranted. In this connection, the Department of Energy is conducting research and development programs related to synthetic fuels".(1)

The same document also indicates, ". . . federal energy research and development funding has been redirected to emphasize basic and applied R&D and to move away from the demonstration [i.e. 6,000 tons per day SRC projects] and commercialization efforts that dominated previous energy research and development policy".(2)

Based on these two statements, it is clear that continuation of the ITSL development program at New Brunswick is fully consonant with national energy policy plan objectives enunciated above. Lummus Crest's objective in continuing its ITSL development program is to bring this technology to a state of sufficient readiness so that when needed large scale demonstration and/or commercialization efforts could proceed in an orderly, efficient and economical manner. Currently planned reductions in the DOE liquefaction budget would have the unfortunate effect of eliminating one of the nation's most promising energy technologies.

As both the pioneers and current leader in ITSL process development, we are firmly convinced that continuation of the Lummus Crest ITSL development program would be a wise investment in the future of our country.

Thank you for your attention and I would be glad to answer any of your questions.

(1) DOE/S-0014/1, October 1983, p. 16
(2) Ibid, p. 14

## ATTACHMENT #1

## ADDITIONAL BACKGROUND INFORMATION ON LUMMUS CREST

Lummus Crest, a wholly-owned subsidiary of Combustion Engineering, Inc., is an international organization providing project management, engineering, procurement, construction, start-up assistance, plant operation, maintenance and training for the petroleum, chemical, petrochemical, pharmaceutical, metallurgical, and oil and gas exploration industries. During the past 75 years, Lummus Crest has successfully completed over 2,000 major and 5,000 minor projects in more than 45 countries. Lummus Crest is currently the managing contractor for the nation's first commercial synthetic fuels plant, the Great Plains Coal Gasification Project in North Dakota, for which construction is 90% complete.

In addition, Lummus Crest maintains a strong R&D capability for developing new and improved processes and optimizing existing ones.

Lummus Crest provides total project responsibility through four operating offices in North America (Bloomfield, Houston, Tulsa, Toronto, Calgary), four in Europe (Northampton, Paris, The Hague, Wiesbaden), one in Brazil, and one in Malaysia. Lummus Crest's worldwide headquarters are located in Bloomfield, New Jersey (Figure 1).

Management and execution of the ITSL process development program is the responsibility of the Engineering Development Center (EDC). EDC facilities are located in both Bloomfield and New Brunswick, New Jersey. At Bloomfield, a 35,000 square foot building houses pilot plant areas, research and analytical laboratories, offices, and a machine shop. In New Brunswick (Figure 2), a 19,000 square foot building on 9.3 acres includes 10,000 square feet of pilot plant area. The existing pilot plants in New Brunswick include five functional units for coal liquefaction research and development, including the 0.25 ton per day ITSL process development unit (Figures 3 & 4). The building also contains a 1,900 square foot analytical laboratory (Figure 5), along with a machine shop and office facilities.

EDC currently has a staff of 125 scientists, engineers, technicians, and support personnel, engaged in research, pilot plant and laboratory development of processes in the synthetic fuels, chemical, petroleum and petrochemical fields. In addition to the engineering divisions of the Company, industrial firms and governmental agencies have extensively utilized the facilities. Currently, 50 of the total 125 EDC personnel are engaged in the day-to-day activities of the ITSL process development program.

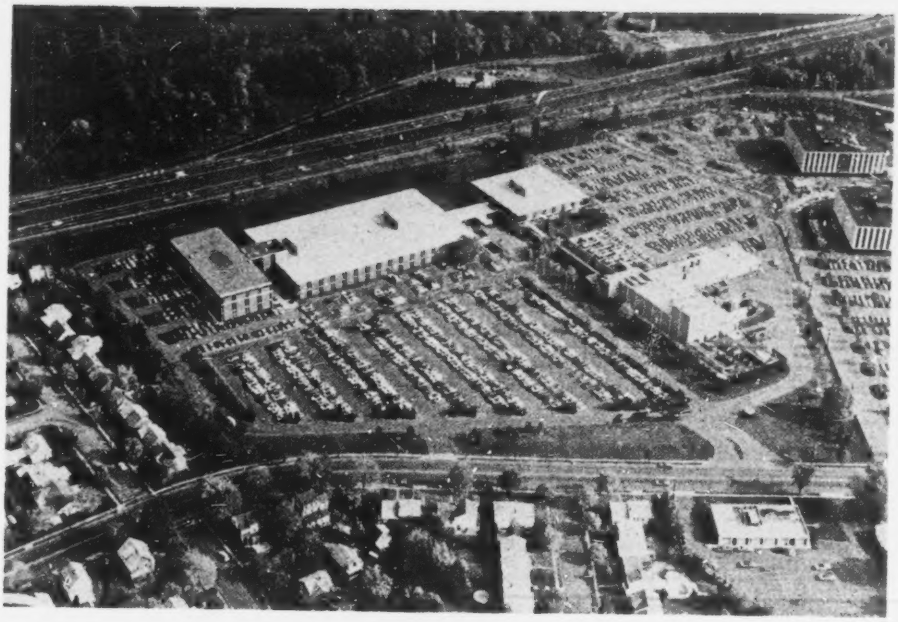

**FIGURE 1**

C-E Lummus' International Headquarters
Bloomfield, New Jersey

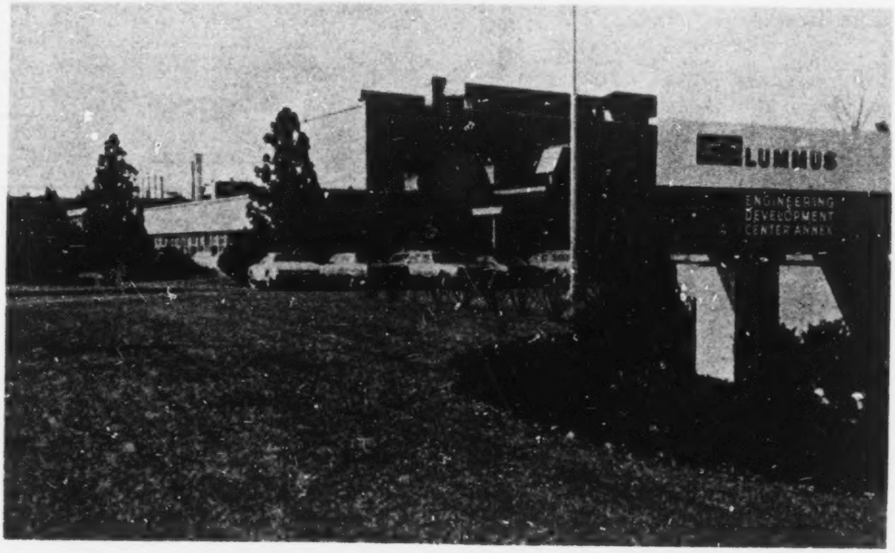
LUMMUS
ENGINEERING
DEVELOPMENT
CENTER ANNEX

**FIGURE 2**

C-E Lummus New Brunswick, New Jersey – E.D.C.
Site of ITSL Development Program

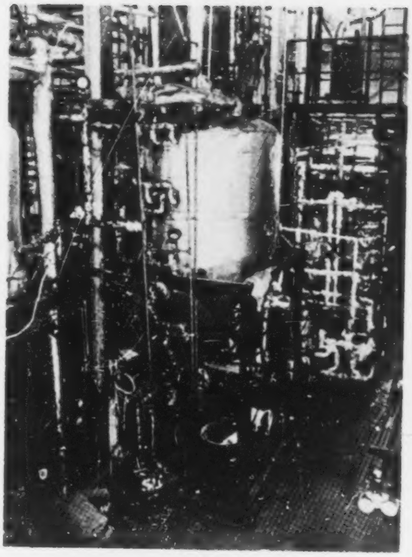

FIGURE 3
Lummus ITSL PDU First Stage Unit

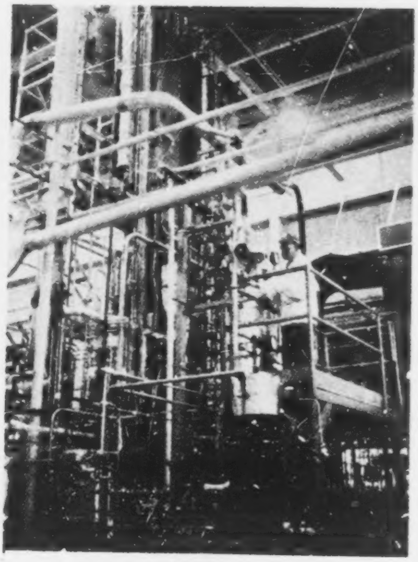

FIGURE 4
Lummus ITSL PDU Second Stage Unit

POSITIVELY
NO SMOKING

FIGURE 5
Lummus ITSL PDU Analytical Laboratory

ATTACHMENT #2

Department of Energy
Pittsburgh Energy Technology Center
P.O. Box 10940
Pittsburgh, Pennsylvania 15236

83-H-015
February 24, 1983

Mr. Michael Peluso
New Proprietary Technology
Lummus Technical Center
The Lummus Company
1515 Broad Street
Bloomfield, NJ 07003

Subject: TECHNICAL ASSISTANCE

Dear Mike:

On behalf of the Department of Energy, I would like to take this opportunity to thank you personally and The Lummus Company for the excellent technical assistance provided to the Wilsonville PDU during Run 242. Without your assistance and advice as well as other personnel within The Lummus Company, it is highly doubtful that the success in demonstrating the scaleup of the Integrated Two-Stage Liquefaction process developed by The Lummus Company could have been achieved. Your advice and assistance along with Mr. Harvey Shindler in the run planning and throughout the operation were an integral part of the milestone run at the Wilsonville PDU.

The Electric Power Research Institute, Southern Company Services, Inc., and Catalytic, Inc. have also expressed their appreciation for the outstanding assistance and advice and cooperation demonstrated by you and The Lummus Company.

Thank you for your technical assistance and advice and cooperation. I hope that we may have the opportunity in the future to work as closely together and may continue the excellent cooperation. Your on-site assistance was invaluable and you and any other personellfrom The Lummus Company are cordially invited to visit the Wilsonville PDU facility at any time.

Sincerely,

Richard F. Hickey

Richard F. Hickey

cc: Al Branchi
Harvey Shindler
Enso Moroni
Nestor Mazzocco
Shelby Rogers

ATTACHMENT #3

**Department of Energy**
Pittsburgh Energy Technology Center
P.O. Box 10940
Pittsburgh, Pennsylvania 15236

January 11, 1984

Dr. H. D. Schindler
C.E. Lummus Company
1515 Broad Street
Bloomfield, New Jersey 07003

Subject: Contract No. DE-AC22-79ET14804, Contract Performance

Dear Harvey,

The Lummus Company has completed the subject contract. All tasks were performed and completed on schedule within budget. The technical reports submitted during the contract period included all the results and data interpretations that were generated during the development program. These deliverables were of the highest quality.

The performance of the Lummus Company was, at all times, highly professional and proficient. This dedication to the development of the ITSL process was instrumental in the success of this contract.

I would recommend Lummus without hesitation for future awards.

Very truly yours,

Eneo R Moroni
Eneo Moroni
Headquarters Program Manager

Nestor J. Mazzocco
Nestor J. Mazzocco
PETC Project Manager

cc:
A. Branchi, Lummus
E. Moroni, HQ
M. Hogan, PETC

Mr. FUQUA. Mr. Schora.

Mr. SCHORA. Yes.

Mr. Chairman and members of the subcommittee, my name is Frank Schora. I am president of Hycrude Corp., formed in 1980 specifically to further research and development efforts for production of synthetic crude oil from Eastern U.S. oil shales. We see eastern shales as a major indigenous source of oil to help supply future U.S. needs.

The strengthening of OPEC a decade ago resulted in a spurt of energy-related investigations ranging from conservation studies to research on alternate energy sources.

One such alternate identified at that time was the Devonian oil shales located in the Eastern United States. Resource assessment studies carried out by the Institute of Gas Technology, individual State geological surveys, and universities indicate that Eastern U.S. oil shale is a major U.S. resource.

The States of Alabama, Indiana, Kentucky, Michigan, Ohio, and Tennessee contain Devonian oil shale deposits sufficiently rich and accessible to enable support of significant oil production for long periods.

The development of eastern oil shale as a supply of domestic liquid fuel is desirable for many reasons. The location of this resource in the Central United States will reassure a reliable and secure supply of high quality crude oil which is in close proximity to oil refineries and markets. It is in an area which has a well established socioeconomic infrastructure and available process water.

The creation of an oil shale industry in the Central United States, I feel, will be a significant asset to the overall well-being of the country. In addition to the reduction of possible trade deficits and the beneficial effects that that may have on the country, the creation of new jobs and the general well-being that will be created by extracting minerals from the ground cannot help to be of great benefit to those areas where the industry is located.

In spite of this opportunity for reduction of oil imports, development of eastern oil shale as an economically competitive source of oil is at a crossroads. The continuation of research programs and the initiation of new programs by the private sector is essentially at a standstill because of the drop in world oil prices, uncertainties in future pricing, and the temporary glut which is partially the result of depressed economies in the free world.

The development of economically viable and environmentally acceptable oil shale retorting processes for eastern shale requires a continuous effort if such processes are to be ready when they are needed in the future. We believe there is no time to be wasted in undertaking such a development, especially when there is no rational basis on which we can project the time when such processes will be needed either on a national security basis or when they will become economically justified relative to importation of oil.

I believe interruption of research and development programs for alternate energy sources such as eastern oil shale is not in the Nation's best interest. In this case, a consistent Government program is needed to foster the continuous development of the eastern oil shale data base. The program should address resource assessment, fundamental and advanced research projects, and environmental and socioeconomic studies. The program should be designed to develop the technology so that the resource and the technology to utilize the resource will be in place when needed.

We, of course, at Hycrude continue to seek support from the private sector.

The technology developed for retorting of Western U.S. shales is not suited to the Eastern U.S. shales because most of the oil producing capability of the shale is not realized. Technology developed for eastern shale can yield two to three times the oil that can be produced by the use of western technology. This cannot be overemphasized if we are to realize the potential of our eastern shale resources. Most of the world oil shale resource is more like eastern than western shale.

For fiscal year 1985, the allocation of $1 million to States which have commercially promising eastern oil shale deposits would provide sufficient funding to further resource characterization studies.

Resource characterization work performed to date has shown that Eastern U.S. oil shale is a major energy resource. Although it has been shown that the States of Alabama, Indiana, Kentucky, Michigan, Ohio, and Tennessee contain commercially promising shale deposits, the level of understanding of the geology of Eastern U.S. oil shale is below that which has been attained in the case of other major domestic energy resources.

A funding level of $2 million we believe is necessary to support fundamental research efforts designed to significantly improve and/or modify existing eastern shale retorting processes and to investigate new, yet to be proven technology.

Over $17 million has been spent to date by the private sector on research and development of moving-bed hydroretorting of Eastern U.S. oil shale. Hycrude Corp. recommends within this $2 million that $0.5 million be used to continue fundamental research activities to further improve oil shale utilization and oil yield in moving-bed hydroretorting. At present, we can obtain yields twice those achievable with the conventional thermal processes. Most of the equipment for work on hydroretorting is in place and available.

We also recommend $0.5 million be used for investigation of a countercurrent baffled fluidized bed to retort oil shale fines which must currently be discarded and $1 million for fundamental research associated with shale beneficiation and an understanding of the chemistry of eastern shales.

An advanced research program of $4 million should be directed toward broadening the data base of the technologies which have yielded enhanced oil recovery from eastern oil shale focusing specifically on moving-bed hydroretorting and other new technologies under development specifically for eastern shales. Hycrude Corp. recommends $1.85 million be allocated to advanced moving-bed hydroretorting research projects which would build upon the results of research efforts funded by the private sector.

We also recommend that $1 million be allocated to investigate the gasification of oil shale fines and shale residue utilizing an existing agglomerating fluid-bed gasifier, and that $0.4 million be allocated to investigate beneficiation of eastern oil shale as a process step prior to retorting. We recommend $250,000 be used to determine the effect of the increase in equipment size on the yields obtained by fast heat-up fluidized bed thermal retorting of eastern shale which has shown promising results to date.

Hycrude Corp. recommends $0.5 million in fiscal year 1985 to carry out advanced research projects on systems such as shale crushing, shale weathering, and oil/water separation which are ancillary to the retorting system itself.

Because it is also important to ensure that the knowledge of effects of environmental and socioeconomic impacts keeps pace with the growing knowledge of resources and processing methods during the development of an eastern oil shale data base, an environmental and socioeconomic issues are site-specific, they are a major concern of state and local governments.

Except for instances in which research is conducted on a specific process, it is advised that funds allocated to perform environmental and socioeconomic studies be allocated to the states which contain commercially promising eastern oil shale deposits.

An allocation of $2 million in fiscal year 1985 is recommended to enable development of preliminary environmental and socioeconomic data to keep pact with other areas of development.

Within this $2 million, $400,000 we believe should be used to define any major environmental impacts of moving-bed hydroretorting and to develop process configurations which minimize these impacts in the most cost-effective manner.

Thank you for the opportunity to testify here today. I will be happy to answer any questions you may have.

[The prepared statement of Mr. Schora follows:]

Statement by Frank C. Schora, President
HYCRUDE Corporation
Before the House Science and Technology Committee
Subcommittee on Energy Development and Applications
Hearings on Department of Energy Budget Authorization for FY 1985
March 8, 1984

Mr. Chairman and Members of the Subcommittee:

My name is Frank C. Schora. I am president of HYCRUDE Corporation, which was formed in 1980 specifically to further research and development efforts for production of synthetic crude oil from Eastern U.S. oil shales. We see these shales as a major indigenous source of oil to help supply future U.S. needs.

The strengthening of OPEC a decade ago resulted in a spurt of energy-related investigations ranging from conservation studies to research on alternate energy sources.

One such alternate energy resource identified at that time was the Devonian oil shale located in the Eastern United States. Resource assessment studies carried out by the Institute of Gas Technology, individual state geological surveys, and universities indicate that Eastern U.S. oil shale is an extensive resource.

The states of Alabama, Indiana, Kentucky, Michigan, Ohio, and Tennessee contain Devonian oil shale deposits which are sufficiently rich and accessible to enable support of significant oil production for long periods.

The development of Eastern oil shale as a supply of domestic synthetic liquid fuel is desirable for many reasons. The location of this resource in the central U.S. will assure a reliable and secure supply of high quality domestic crude oil which is in close proximity to oil refineries and markets. The resource location is in an area which has a well established socioeconomic infrastructure and available process water.

In spite of the opportunity for the reduction of oil imports which development of Eastern oil shale poses, the development of Eastern oil shale as an economically competitive source of synthetic crude oil is at a crossroads. The continuation of research programs and the initiation of new research programs by the private sector is essentially at a standstill because of the drop in world oil prices, uncertainties in their future pricing, and the temporary glut which is partially the result of depressed economies in the free world. However, the development of economically viable and environmentally acceptable oil shale retorting processes requires a continuous effort if such processes are to be ready when they are needed in the future. We believe there is no slack that can be allowed in such a development, especially when there is no rational basis on which we can project the time when such processes will be needed either on a national security basis or when they will become more economically justifiable than continued importing of oil.

Interruption of research programs for alternate energy sources such as Eastern oil shale is not in the Nation's best interest. In this case, a consistent government program is needed to foster the continuous development of the Eastern oil shale data base.
The program should address the key areas which will develop the data base on Eastern oil shale. These areas are: resource assessment, fundamental and advanced research projects, and environmental and socio-economic studies.

For FY '85 the allocation of $1.0 million to states which have commercially promising Eastern oil shale deposits would provide sufficient funding to further resource characterization studies which would provide a better understanding of the geology and geochemistry of Eastern oil shale. The amount of resource characterization work which has been performed on Eastern oil shale varies from state to state. The funding level recommended would provide for the continuation of studies which assess the richness of the oil shale resource and the feasibility of commercial development.

The inclusion of fundamental research projects in the program will ensure the continued entry of possible new process concepts designed specifically for full utilization of Eastern oil shales. Because Eastern oil shales do not respond as favorably to conventional retorting processes as Western shales, a fundamental research program is necessary to continue the development of technologies which improve the economics and efficiency of synfuels recovery from Eastern oil shales. Such a program will provide data in a form that can be readily utilized by process developers in future design efforts.

A funding level of $2.0 million in FY '85 is necessary to support fundamental research efforts designed to significantly improve and/or modify existing Eastern shale retorting processes and to investigate new, yet to be proven technology.

Over $17 million has been spent to date by the private sector on research and development of moving-bed hydroretorting of Eastern U.S. oil shale. HYCRUDE Corporation recommends $0.50 million to continue fundamental research activities to further improve oil shale utilization and oil yield in moving-bed hydroretorting using existing equipment. For example, modifications to the retort and the process operating conditions would enable utilization of most of the fines generated during shale crushing thereby improving resource utilization. Also, development of a technique to control the oil droplet size in the retort would prevent condensation of the oil vapor on incoming raw shale and its subsequent revaporization and cracking which reduces oil yield.

HYCRUDE Corporation also recommends $0.50 million for the investigation of a countercurrent baffled fluidized bed to retort oil shale fines which would increase the utilization of shale fines which must currently be discarded.

The advanced research program should be directed toward broadening the data base of the technologies which have shown enhanced oil recovery from Eastern oil shale. The advanced research program should focus on moving-bed hydroretorting and other new technologies developed specifically for Eastern oil shale. These processes have relatively near-term (within the next decade) prospects for commercialization. An allocation of $4.0 million in FY '85 will allow for continuation of advanced research on Eastern shale retorting technologies.

HYCRUDE Corporation recommends $1.85 million be allocated to moving-bed hydroretorting advanced research projects which would build upon the results of research efforts funded by the private sector. These research activities would concentrate on improving the economics of the process by reducing the consumption of hydrogen and ensuring that the most efficient shale mining, crushing, and auxiliary processing systems have been applied to oil shale retorting. Experimental work would also be performed in existing equipment to widen the Eastern shale data base and to provide analytical data necessary for environmental studies. Also, it is recommended that $1.00 million be allocated to investigate the gasification of oil shale fines and residue utilizing an existing ash agglomerating fluid bed reactor, and that $0.40 million be allocated to investigate the economics of beneficiation (enrichment) of Eastern oil shale.

Because it is important to ensure that the knowledge of effects of environmental and socio-economic impacts keeps pace with the growing knowledge of resources and processing methods during the development of an Eastern oil shale data base, an environmental and socio-economic study program is recommended. Since the environmental and socio-economic issues are site-specific, they are a major concern of state and local governments. Except for instances in which research is conducted on a specific process, it is advised that funds allocated to perform environmental and socio-economic studies be allocated to the states which contain commercially promising Eastern oil shale deposits.

An allocation of $2.0 million in FY '85 should enable preliminary environmental and socio-economic data to keep pace with other areas of development. From a process standpoint HYCRUDE Corporation recommends $0.40 million to investigate the environmental impacts of moving bed hydroretorting.

Thank you for this opportunity to present my views to you today. I will be happy to answer any questions you may have.

# Eastern Oil Shale

# Research and Development

# Recommendations FY '85

## PROGRAM FACT SHEET

### RESOURCE CHARACTERIZATION

Resource characterization work performed to date has shown that Eastern U.S. oil shale is a major energy resource. Although it has been shown that the states of Alabama, Indiana, Kentucky, Michigan, Ohio, and Tennessee contain commercially promising oil shale deposits, the level of understanding of the geology of Eastern U.S. oil shale is below that which has been attained in the case of other major domestic energy resources.

Further resource characterization is necessary to provide a better understanding of the geology and geochemistry of the resource. This will help to identify areas best suited for commercial development and will also help to establish a baseline for environmental studies. This work can be accomplished at a comparatively modest level of funding because of the volume of basic geological data which can be used as a starting point.

Area-wide maps detailing resource composition and richness as well as surveys to determine potential by-product metals will aid in energy resource evaluation and mine planning.

Correlations of the oil yield from various processes with oil shale geochemistry and modeling of the distribution of organic materials, minerals, and fossils would simplify the evaluation of the commercial potential of oil shales in a given area.

This knowledge would help state and local governments to pre-evaluate the impact of commercial-scale oil shale development in their areas. Resource characterization work is therefore best performed by individual state agencies.

**HYCRUDE Corporation recommends that $1.00 MM in FY '85 be allocated to concerned states for resource characterization work.**

## FUNDAMENTAL RESEARCH

### Improvement of Yield in Moving-Bed Hydroretorting

Moving-bed retorting of oil shale in a hydrogen-rich atmosphere at elevated pressure (hydroretorting) has been proven to result in enhanced oil yields for Eastern shale retorting which are up to twice the oil yields obtainable utilizing conventional thermal retorting technologies. Fundamental research in two areas could result in improvements in oil shale utilization and oil yield.

Currently, 10% to 20% of the raw shale must be discarded without processing of any sort because during the shale feed preparation (crushing and screening) a portion of the shale becomes too fine to be retorted in a moving bed under current operating parameters. In order to avoid wasting this portion of the resource, fundamental research work should be performed to modify the process operating conditions and/or reactor mechanical configuration to broaden the capacity of moving-bed hydroretorting to enable processing of fines.

Oil refluxing (condensation of oil vapor on incoming raw shale and its subsequent re-vaporization) reduces the efficiency of moving-bed countercurrent oil shale retorting processes because a significant portion of the oil reacts with hydrogen to form hydrocarbon gases when the oil re-vaporizes. The investigation of mist formation systems could result in control of the oil droplet size which would help to minimize refluxing, thereby improving the oil yield and process efficiency of countercurrent moving-bed hydroretorting systems. Development in this area could also be of significant assistance to conventional thermal processes.

**HYCRUDE Corporation recommends $0.50 million in FY '85 to research methods to improve the oil shale utilization and oil yield in moving-bed hydroretorting.**

### Process Chemistry

Research projects which investigate both the chemistry of specific processes and general mechanisms of retorting chemical reactions are necessary. Specific areas in which further research is warranted include Eastern oil shale beneficiation process chemistry studies. Oil shale beneficiation, or concentration of the organic content of an oil shale, results in a greatly enriched oil shale feedstock which significantly reduces material handling capital and operating costs.

Existing thermal retorting processes have more complete energy recovery when spent shale is burned. However, Eastern oil shale has a higher sulfur content than Western oil shale. Therefore, another area which should be investigated is the direct combustion of Eastern shale (raw or spent). Another process chemistry study which would help to provide a better understanding of the mechanism of retorting chemical reactions is the identification of the primary and intermediate reaction products of Eastern oil shale. Furthermore, the investigation of a variety of retorting atmospheres such as steam, methane, carbon monoxide, etc., should be investigated to optimize operating conditions for achieving possible enhanced oil recovery.

HYCRUDE Corporation recommends $1.00 million in FY '85 to research Eastern oil shale retorting process chemistry.

## Novel Methods for Fines Processing

Present technologies for processing shale fines do not incorporate efficient countercurrent heat recovery from the processed shale because oil refluxing causes the fines to plug up the retort. The use of a countercurrent baffled fluidized bed that incorporates oil droplet size control can retort shale fines without plugging using highly efficient countercurrent gas/solids contacting.

HYCRUDE Corporation recommends $0.50 million in FY '85 to investigate retorting of shale fines in a countercurrent baffled fluidized bed.

## ADVANCED RESEARCH

### Advanced Hydroretorting Studies

The process chemistry of moving-bed hydroretorting has been proven at the fundamental research level and because of the increased oil yield and quality obtained, advanced research is now warranted. Reduction of the hydrogen consumed in the process reduces both capital and operating costs. Methods for reducing the consumption of hydrogen in moving-bed hydroretorting should be further researched. The process economics can also be substantially improved by performing a sensitivity analysis on the entire system (shale mining, crushing, and all processing sub-systems) to ensure that the application of the most efficient systems for oil shale retorting have been included. Hydroretorting assays, continuous moving-bed hydroretorting tests, and detailed chemical analyses of products should be performed for a variety of Eastern oil shales to broaden the data base necessary for continued process development and environmental studies. Additionally, a preliminary study of the use of oil produced by moving-bed hydroretorting should be performed to evaluate its potential use for aviation turbine fuels or chemical feedstocks.

**HYCRUDE Corporation recommends $1.85 million to be allocated to moving-bed hydroretorting advanced research projects.**

### Oil Shale Beneficiation

Beneficiation (enrichment) of the organic material (kerogen) in oil shale results in a more concentrated shale feed. The economic trade-off between beneficiation costs and the subsequent oil shale retorting costs should be evaluated for several processes in order to determine the optimum level of beneficiation.

**HYCRUDE Corporation recommends $0.40 million in FY '85 to carry on advanced oil shale beneficiation studies.**

### Scaleability of Novel Eastern Shale Retorting Processes

The scaleup issues (oil yield versus equipment size) should be investigated for novel methods for Eastern oil shale retorting including fast heatup, fluidized bed thermal retorting, which has shown promising oil yields to date.

**HYCRUDE Corporation recommends $0.25 million in FY '85 to carry out this work.**

## Gasification of Fines and Residue Shale

Oil shale fines and shale residue contain carbon which can be gasified in a spent shale-agglomerating fluidized bed to produce additional gaseous fuel. Potentially leachable material could also be immobilized in the form of non-leachable spent shale agglomerates.

> **HYCRUDE Corporation recommends $1.00 million in FY ' 85 to investigate the gasification of Eastern oil shale fines and residue in a spent shale-agglomerating fluidized bed.**

## Auxiliary Process Studies

Advanced research work should be performed in several areas which are auxiliary to any Eastern oil shale retorting project. The method of preparation of oil shale feedstock by crushing and screening is important to all Eastern shale retorting technologies, as this consumes energy and generates fines which cannot be retorted utilizing presently available technology. Methods for oil shale crushing which minimize energy consumption and produce a closely controlled size range of crushed shale, thereby reducing fines waste, should be investigated.

It has been discovered by several researchers that there is a loss of oil yield potential from thermal processing after mined shale is exposed to the atmosphere (weathering) over periods as short as several days . It is important to investigate the extent of raw shale weathering as a function of exposure time, shale particle size, etc., so that appropriate action can be taken to prevent significant loss of potential oil yield. A research effort should be supported which investigates the cause and effect of raw shale weathering on retorting oil yields.

The efficient separation of water and fines from the oil produced during retorting is an important element of producing raw shale oil of consistent quality. Improved methods for separation of water and fines from shale oil such as the use of electrical fields should be developed and tested.

> **HYCRUDE Corporation recommends $0.50 million in FY '85 to carry out advanced research projects on systems such as shale crushing, shale weathering, and oil/water separation which are ancillary to the retorting system itself.**

## ENVIRONMENTAL AND SOCIO-ECONOMIC STUDIES

### Environmental Impacts of Hydroretorting

It is important during the development of an Eastern oil shale data base to ensure that the evaluation of environmental and socio-economic impacts keeps pace with the growing knowledge of resources and processing methods.

A study should be conducted to further define the major environmental impacts of moving-bed hydroretorting and to develop process configurations which minimize these impacts in the most cost effective manner.

HYCRUDE Corporation recommends $0.40 million in FY '85 to carry out this work.

### Environmental and Socio-Economic Studies

Since many environmental and socio-economic issues are site-specific, they are a major concern of state and local governments. Except for instances in which research is conducted on one specific process, it is advised that monies to perform environmental and socio-economic studies be allocated to the states which contain commercially promising oil shale deposits.

It is recommended that fundamental experimental studies be conducted to study the effects of differing retorting technologies and methods of mine reclamation or spent shale leaching.

During retorting, a significant portion of the sulfur present in the raw shale ends up in product gas and water in one form or another, and must be removed. Sulfur in the spent shale also has the potential to produce leachates. Techniques should be investigated to remove sulfur from raw shale prior to retorting which would eliminate the need for, or reduce the size of, sulfur removal processes.

The impact of re-contouring Eastern oil shale resource areas and expansion of their use for agricultural purposes should be studied. The effects on water balances and the social infrastructure should be examined.

It is recommended that preliminary studies be performed to identify areas which have the potential to be improved after land reclamation by revegetation with plant species which could not survive on the land before reclamation.

Studies should be conducted to determine the probable water requirements for a mature Eastern oil shale industry on a state-by-state basis, and the environmental impact of supplying those requirements should be investigated.

A preliminary study or studies should be performed to identify potential socio-economic impacts of the area-wide development of an Eastern U.S. oil shale industry.

HYCRUDE Corporation recommends $1.6 million in FY '85 be allocated to the states which contain commercially promising Eastern oil shale deposits to conduct general environmental and socio-economic studies of concern to a developing oil shale industry.

Mr. FUQUA. Mr. McElwain.

Mr. MCELWAIN. Before I summarize my statement, I have been asked to request to be filed for the record two statements, one by David Brown, president of the MHD Industrial Forum, and the other by Mr. Jack Sherick, president of Montana States Energy, Inc.

Mr. FUQUA. Without objection.

[The prepared statements of Messrs. Brown and Sherick follow:]

## PREPARED STATEMENT OF DAVE BROWN, PRESIDENT, BOARD OF DIRECTORS, MHD INDUSTRIAL FORUM

INDUSTRIAL FORUM

Dear Mr. Chairman and members of the Committee:

I am submitting testimony in support of a continuing national Magnetohydrodynamics (MHD) program directed toward commercializing this technology as soon as possible. However, in deference to the newly appointed Assistant Secretary for Fossil Energy, William Vaughan's invitation to the MHD Industrial Forum and the Edison Electric Institute's MHD Utility Task Force to work with DOE on a national MHD development program, we ask to reserve our final position on program direction and funding. Industry still supports a $40 million DOE FY 1985 MHD program over DOE's $17.8 million budget request.

The FY 1985 budget request of the Administration for developing MHD power generation is a most welcome change from past years. We are particularly pleased that the changes in high level department personnel have included individuals who recognize the importance of fossil energy and coal. Recent discussions with William Vaughan have been very positive and encouraging. This is not only because of his apparent positive attitude toward development of the MHD technology and fossil energy in general but also because of his desire to involve

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industry in the planning of the Department's MHD program. It is most unfortunate, however, that DOE planners did not seek the counsel of industry prior to proposing a program intended to place the private sector in a position to commercialize the MHD technology.

While the Forum is very positive about DOE's MHD program direction and the new Assistant Secretary's request for industry involvement, we must point out for the record the problems with the FY 1985 budget submission. Unfortunately, the budget and plan which Mr. Vaughan inherited from his predecessor (which is contained in the budget before this Committee) was not presented with a continuing national MHD program in mind, especially given the low budget request and the requirement for fifty percent private cost share as a pre-condition for continuing the present program. The proposed multiyear program concept is essential. However, the technical portion (Phase I) of the plan ignores the state of the MHD technology. The purpose of the Phase I scientific research program appears to emphasize the basic research activities which were the focus of the program in the early 1970's rather than the research needed to support the engineering scale-up required at this stage of MHD technology development. The proposed Phase I concentrates on the wrong problems. The proposed Phase II 80 Mw thermal integrated test facility (ITF) operation would presumably abort all ongoing work at the 50 Mw thermal scale at the Component Development and Integration Facility (CDIF) and supporting component manufacturers just at the time when the first critical coal fired topping cycle tests are being initiated. In addition, the ongoing bottoming cycle test program at the Coal Fired Flow Facility (CFFF) may be discontinued in mid-stream. If true, these terminations would be a tragic waste of the more than $300 million that has been invested to date just to get that test data. An integrated test facility at the 80 Mw thermal level as an end to the government program will not meet the needs of the utility industry, nor meet the government's goal of developing an adequate knowledge base that will enable private idustry to apply the technology. The proposed program cost estimates are so low that a cost overrun is guaranteed.

While this is not the place to go into a detailed technical evaluation of this plan (which we will do with the department), a quick overview of DOE plan deficiencies will be useful. The DOE Phase I scientific research program proposal identifies a variety of technical issues associated with MHD which it indicates must be resolved. In fact, the budget description of these issues appears to be a cut-and-paste job of old documents found around the office. Let me address some examples. The development of high temperature air heaters is identified as a critical problem. The fact is high temperature air heaters will not be needed for first generation MHD plants, since the high temperature requirements can be met using oxygen with little or no economic impact to plant operation. Design and operating conditions required to suppress ash fouling effects were identified as a critical scientific problem when in reality, they are engineering questions which are being resolved at the Coal Fired Flow Facility (CFFF) at the University of Tennessee. The recovery and regeneration of potassium salts and seed are also engineering problems whose solution the CFFF was designed to provide.

Coal combustors and channels were identified as areas needing research to obtain data on erosion, corrosion, combustion kinetics for different coal types. These again are engineering questions which cannot be resolved through small scale tests. They must be resolved through engineering testing in facilities such as those presently being used at Avco, TRW and the CDIF. Superconducting magnet technology is well established and "additional" research is not needed. A superconducting magnet needs to be designed for use in a large scale MHD power plant, but this is not critical and can be delayed. Current consolidation, power conditioning and inverter circuitry have worked well at

Avco and the CDIF. While improvements are desirable in all the above areas, the state of the art of all these systems is sufficiently advanced and none are "show stoppers" for achieving early commercial MHD plants.

The accomplishments which the new DOE FY 1985 plan calls for would be of "scientific" interest but of little engineering value. They address problems that already have been solved and do not allow for proceeding with the more pressing MHD technology engineering questions. For example, efforts like the following must be completed as quickly as possible: completion of the coal combustor at TRW and its installation at the CDIF for coal-fired testing; continuation of coal-fired MHD channel testing at Avco's 20 Mw thermal test facility; provision of the necessary equipment and operating funds to the CFFF to enable that important facility to complete seed regeneration, environmental control technology engineering development and other critical bottoming cycle development.

The results of CFFF engineering, the channel work at Avco, the TRW combustor effort and diagnostic and instrumentation control equipment work at Mississippi State University need to be integrated quickly into the CDIF as the final step before any near commercial demonstration. The DOE MHD plan for FY 1985 ignores the well thought out merits of its existing program and contemplates taking no advantage from several years of progressive and productive MHD technical work.

The concept of an integrated test facility (ITF) is strongly supported by the industrial and utility sector. However, a scale of 80 Mw thermal as proposed in DOE's Phase II is not much larger than the present 50 Mw thermal test capability at the DOE CDIF. Yet the proposed 80 Mw thermal ITF project is likely to require as much as $200 million over several years. It is simply unnecessary and would needlessly stretch out program schedules and greatly increase program costs without any significant gain. Key MHD phenomena that are difficult to observe at a 50 Mw thermal scale will still be difficult to identify at 80 Mw thermal.

The utility industry in a study recently completed for the State of Montana Department of Natural Resources and Conservation outlines a set of performance requirements which must be met before the utility industry could, with reasonable expectation, proceed with commercialization of the MHD technology. An integrated system test at the 80 Mw thermal scale will simply not meet these rquirements. While some additional risks are involved in going from the present scale of testing to a facility on a scale of 350 Mw thermal (the 1983 MHD Forum's proposed approach), the resulting reduction in overall program costs and development time would jusfity these technical risks.

If the DOE view is that an intermediate scale integrated system test is needed to minimize government involvement programmatically and financially and yet reach a reasonable technical end to Federal government activity, the intermediate unit should still be configured and operated as a retrofit at an actual electric utility site. The size of that retrofit should perhaps be at some appropriate intermediate scale between the DOE proposed 80 Mw thermal (20 Mw electric) and the Forum's and utilities recommended 350 Mw thermal (120 Mw electric) size plant. Before deciding on the final size a more detailed analysis should be conducted relative to specific requirements at appropriate utility sites. From a scientific and engineering viewpoint this will allow the critical MHD phenomena to be studies in a long duration, slagging environment (which should be a major scientific objective of the Federal program) and yet be representative of a projected commercial plant environment. If the DOE proposed program objective is indeed to take the technology to a logical Federal conclusion (as stated in the FY 1985 DOE budget request), the successful operation of a cost shared integrated test facility by industry in a "real world" electric utility environment would be a minimum requirement.

The DOE fifty-fifty cost share was unilaterally proposed by DOE. This is an issue which must be jointly resolved between DOE and industry. That percentage cost share seems inappropriate for a technology at this early stage of engineering development, particularly in a government owned facility as proposed by DOE which has little potential for utilities to gain the necessary industrial operating experience. A more logical approach will provide a better vehicle for industrial financial participation and will attract greater industrial and utility interest.

Mr. Chairman, it is most unfortunate that whoever developed the DOE FY 1985 MHD plan did not take into consideration the strategy which was completed for the MHD Industrial Forum over several months in 1983 by a committee of distinguished representatives of the utility industry, its suppliers, the MHD development community and architect and engineering firms specializing in the construction of utility plants. In preparing the MHD Forum's strategy for commercialization, we took great care in selecting committee members who had considerable MHD expertise and extensive experience in developing and costing power plants for utilities. As a consequence I am confident that both strategy and cost estimates as they appear in the Forum strategy are the best available. You will also note that industry volunteered to assume thirty to forty percent of the cost of the retrofit program.

I might point out that the DOE plan before you also ignores the findings of its own study conducted by Gilbert Associates in compliance with the FY 1983 Continuing Resolution. The recent DOE Inspector General's report on the MHD program contradicts the Departments proposed FY 1985 MHD program approach. That report also pointed out policy level management problems at DOE contrary to Congressional direction while finding MHD program level management and technical progress were positive.

The MHD community will be meeting with Assistant Secretary Vaughan and his representatives at his invitation in the coming weeks to work out a program on which the department and industry can agree. While we believe the Committee must understand the negative nature of the Department's proposed MHD program direction, we believe the proposed budget request of $17.8 million is a step in the right direction, and we are most positive towards the Assistant Secretary's desire to work together. We will let the Committee know prior to your markup as to the success of this effort. We would ask the Committee's indulgence to allow us to present further written testimony on the DOE proposed MHD program at that time.

We appreciate this opportunity to present written testimony for the record and will be available to discuss the FY 1985 DOE MHD program budget at your request. Your continued support of the MHD program would be most appreciated.

## PREPARED STATEMENT OF JACK SHERICK, PRESIDENT, MSE, INC.

Mr. Chairman and Members of the Committee:

I am pleased to submit this testimony in support of the continuation and increased funding of magnetohydrodynamics (MHD) development. In this testimony I will show that:

1) There is a need for the development of fossil energy technology to meet our continued energy demand in this country and such technology must reflect the cleanest, most efficient options available;

2) MHD offers the greatest potential of any coal conversion technology being considered;

3) There is and has been substantial nonfederal government interest and financial support for MHD development to date, but the federal investment is necessary for the development to proceed;

4) The technology has reached the point where increased scale integrated system testing is required to assess the commercial viability of MHD; and

5) The strategy proposed by DOE in the FY-85 Budget request is sound but the scale of the final phase of testing is inadequate. To take MHD to the point where industry can develop it is an end point that must be agreed upon by both DOE and the potential industrial/utility participants.

Through these points, I hope to lay the base for a continued U.S. Government (DOE) funded program of a minimum of 40 million dollars in FY-85 and continued support of an advanced test system as described in legislation currently pending before Congress.

Coal has been in the past and continues to be the dominant fuel for electric power generation in the United States. According to the DOE "Energy Projection to the Year 2010," 50% of the electric power produced in this country in 1980 was produced in coal-fired power stations. This percentage is expected to increase to 59% by the year 2000. The "National Policy Plan" estimates that by the year 2000 approximately 438,000 MW of additional electric generating will be required to replace older units being retired and to meet the increased demands for electric energy. Approximately 325,000 MW of the capacity is expected to be generated in coal burning power plants. With this increased reliance on coal it is important that this new generating capacity utilize the cleanest, most efficient and effective technology available. Environmental problems associated with the utilization of coal, such as acid rain, CO2 emissions, (which contribute to the greenhouse effect), solid waste from slag/scrubber sludge, thermal pollution and others, can be mitigated through the use of this advanced technology.

Furthermore, the use of this advanced technology offers direct and significant cost savings to the utility rate payers and conserves valuable limited natural resources. With only 25% of the required additional capacity needed by the year 2000 under construction, it makes sense to invest now in the development of efficient technology. The payback potential is considerable both in terms of environmental and economic benefits. Reducing the cost of electricity 5 mills through the use of cleaner more efficient processes would, for the period of 1990 to 2010, save the utility rate payer 90 billion dollars (and pay back the cost of development many times).

Of the advanced coal conservation technology currently under development (e.g. molten carbonate fuel cells, MHD, high temperature gas turbine, and pressurized fluidized bed), MHD offers the greatest potential to favorably impact our energy future. Only MHD offers direct conversion of coal to electricity while displaying the highest potential efficiency of near 50% or greater. Besides the application of MHD in base load electric power generation, there is large potential application in power intensive/high temperature industrial processes, as well as applications in the defense area. In addition to all these advantages only MHD offers long-term potential for application with advanced power conversion systems such as fusion, and spinoffs which include cryogenic and superconducting magnetic applications.

Significant advances have been made in the development program since 1972. Test durations have increased from a few minutes at relatively small scales to hundreds of hours at the 20 MWt level at AVCO-Everett Research Laboratory and of several hours duration at the larger 50 MWt scale at the CDIF. The technology has reached a point in its development where experimental programs need to focus on the important issues essential to commercialization, such as scale of components, integrated system performance. These needs were confirmed in the "MHD Program Evaluation" performed by Gilbert Associates, Inc., for the DOE under Congressional mandate by PL Bill 97-394 and more recently in the MHD assessment performed by the Electric Power Research Institute (EPRI).

The program proposed by the DOE in the FY-85 budget request contains a two phase, multi-year program which recommends an integrated coal-fired system testing, backed up by supporting scientific research. Completion of the proposed program would bring the DOE involvement in the MHD development to a conclusion. This is a sound concept but the scale at which the integrated testing is recommended, 80 MWt, will not meet the needs of the private sector for commercialization of the technology. The 80 MWt scale is too small to address the critical performance scale up and plant economic issues and therefore represents an inadequate technological data base from which industry can commercialize the technology. Industry has previously demonstrated its interest in the MHD technology and its willingness to share responsibilities for its development. Over 50 million dollars have been invested by the private sector over the past years or more. (Attachment 1.) The Southern California Edison Company continues to privately investigate the MHD retrofit/coal conversion options for its oil-fired power plants. EPRI continues to support its investment in the MHD inverter at the CDIF and is also funding current consolidation studies through three different groups. The utility industry individually and collectively, through the Edison Electric Institute task force and EPRI, has been an active participant in the commercialization studies such as those funded by the State of Montana Department of Natural Resources and Conservation. The development risk is too high for the utility industry to assume total responsibility for MHD development beyond the 80 MWt level. If government participation is not continued to a larger scale of testing, there is concern that the development will not continue and the federal investment to date in the technology will be lost without achieving the objective of commercializing MHD.

The U.S. presently has an unquestionable lead in coal-fired MHD technology but other countries have made strong commitments to the development of the technology. A commercial scale, 500 MWe, gas-fired unit is already under construction at the Ryazan Power Plant in the Soviet Union. With construction of this plant it is no longer a question whether MHD will be commercialized or not. It is being commercialized in the U.S.S.R. The U.S. cannot maintain the advantage it has had by passing responsibility for MHD development to industry at a scale where industry cannot be reasonably expected to successfully assume that responsibility.

What is needed at this point is an MHD development program establishing the cooperative efforts of the utility industry/component manufacturers and the Department of Energy which can be definitized and financially committed to by both. This last point is key to significant large scale testing by industry. As pointed out in the Inspecter General Report on the MHD program, numerous program plans have been developed by DOE at the program manager level, but none to date has been formally issued by DOE management. Industry has shown an interest and willingness to participate in MHD developoment, but before the financial and physical commitment required from industry can be realistically expected, the government must demonstrate that they are willing to be a responsible partner in such an alliance.

While the previous stated multi-year commitment is required to accomplish the end goal, near term MHD program results/progress continue. At the CDIF oil-fired MHD power generation characterization data at the 50 MWt level was obtained for comparison to future coal-fired MHD power generation data. The EPRI supplied inverter has been used to supply over 5 megawatt-hours of MHD produced electrical power to the Montana Power Company grid. EPRI participated in partially funded MHD test measurements at the CDIF and AVCO that provided data needed for future electrical power takeoff equipment related to the MHD channel. Currently the CDIF facility is undergoing modifications in preparation for the TRW coal-fired combustor (CFC) scheduled to arrive at the CDIF in June of 1984.

Future plans include initial testing of just the CFC and then extensive MHD power generation testing with the new CFC and the existing AVCO channel. This indepth characterization testing will provide much engineering insight into several of the areas of concern in DOE's proposed scientific research portion of the two phase MHD program. This and other future testing results from the DOE contractors will continue to progress the development of MHD.

Thank you for the opportunity to submit this testimony. I hope the attributes of MHD are recognized. I strongly feel that this technology can play a key role in helping to solve this nation's energy and environmental needs.

I urge you to continue your strong support of the national MHD program.

ATTACHMENT I

## INDUSTRY AND STATE GOVERNMENT INVESTMENT IN MHD

To date, industry and state governments have invested over $50 million in research and studies on the MHD technology. These investments are summarized below:

I. Utility Industry

A. Electric Power Research Institute (EPRI)

Since 1974 EPRI has funded $8-$10 million in various studies on MHD. In addition, EPRI funded the design, construction and installation of the $2 million inverter at the CDIF. EPRI has budgeted $1.5 million for MHD over the next five years.

B. Edison Electric Institute

The 21 member EEI Task Force and MHD (Utilities MHD Users Group) has been meeting twice yearly on MHD for the past three years. In addition, the Task Force members have participated at their own expense in the studies sponsored by the State of Montana DNRC. Contribution of engineering services and travel by EEI Task Force members and the utilities is about $250,000.

C. Southern California Edison

SCE has funded $600,000 - $700,000 of MHD work during the past five years. In addition, an estimated $350,000 will be beginning in FY-84.

III. Industry

A. Reynolds Metals Company

Over the 10 year period, starting in the mid 1960's, Reynolds Metal invested approximately $5 to $6 million in MHD research.

B. TRW Incorporated

To date, TRW has invested about $8 million in MHD including about $3 million in their MHD combustor test facility.

C. AVCO

AVCO has been involved in MHD research for over 25 years. During the 1960 to 1970 time period, AVCO with a group of utilities, invested over $10 million in MHD research.

D. Westinghouse

Westinghouse has been involved in MHD Research since 1939 and has invested $15-$20 million in research on the technology since then.

E. General Electric

In the 1950-1960 time period, General Electric invested $1-$2 million in MHD research.

F. University of Tennessee Space Institute

UTSI has invested about $500,000 in facilities for MHD research plus, as noted in II.B., the State of Tennessee provided a $2.2 million building about one-half of which is dedicated to MHD.

D. Montana Power Company

The MPC has actively supported the MHD technology for a number of years. MPC has submitted proposals to the DOE for a cooperative project at their planned Salem Plant and is one of the utilities that would be very receptive to participating in the MHD Industrial Forum concept.

E. American Electric Power Services Co.

In the 1960's, AEP supported approximately $1 million of MHD work.

II. State Governments

A. The State of Montana through its Department of Natural Resources and Conservation (DNRC) has funded $500,000 to conduct an engineering assessment of retrofitting MHD. In addition, utility contribution to this project as noted in I.B. has been in the order of $250,000.

B. State of Tennessee

The State of Tennessee provided a $2.2 million building to the University of Tennessee Space Institute of which one-half is dedicated to MHD research.

C. Others

Several states other than Montana have expressed interest in supporting coal technologies. Specifically, the State of Alaska has been considering funding studies in MHD application in Alaska.

Mr. McElwain. Montana Power Co. is an energy company which serves as an electric and gas utility to the western two-thirds of Montana. We also have major coal mining operations in Montana, Wyoming, and Texas that are operated under our wholly owned subsidiary, Western Energy Co.

Last year, that company mined approximately 10 million tons of coal and by the late 1980's, will be mining approximately 24 million tons of coal a year in the three States it currently operates in.

For a long time, my company has been very interested in the matter of magnetohydrodynamics, which has had greater emphasis put on it since the Arab embargo.

We believe that it is absolutely necessary in this country that we begin to internalize our energy capability, and basically through the greater utilization of our vast coal resources. The U.S. possesses over 35 percent of the known coal resources in the world, some 450 billion tons.

The States of Montana, Wyoming, and North Dakota possess approximately 45 percent of that coal reserve with Montana having approximately 120 billion tons of reserve.

If we are truly to attack the problem of energy vulnerability, we must do everything possible to utilize these vast coal resources.

As a utility executive, I simply cannot be satisfied with the present conversion factor of coal to electricity of approximately 30 to 35 percent efficiency. This is particularly true when there is a technology such as MHD which offers an ability to increase that efficiency to as much as 45 to 55 percent.

The commercialization of this process in my judgment represents one of the greatest contributions that can be made to the efficient utilization of our coal resources, as well as making good conservation sense. If we can raise our utilization factor of coal by even 50 percent, this makes a great contribution, not only to our energy source supply but also to the capability of transporting coal to its place of use, because every ton of coal shipped, if MHD is commercialized, would render 50 to 75 percent more energy than is currently the case.

The process presents the only technology for the direct conversion of coal to electricity on the scene today that increases efficiency as well as meets environmental standards and goals.

It is a relatively simple conversion process which moves a hot conductive gas through a strong magnetic field which then causes current to flow in the gas. There are no moving parts which should allow the process to run for sustained periods of time. It has the highest potentially efficiency of all of the new coal-burning technologies. Its combustion process inherently controls $SO_x$ and $NO_x$.

The impacts of burning coal 50 percent more efficiently also have tremendous benefits of reducing related environmental impacts through less mining, less transportation, less effluents.

There are no technology breakthroughs required to proceed with this promising conversion process. We are at the point where we need to prove its efficiency, economics, and commercialization of scale. With all of this potential and the possibility of lower cost electricity, I believe MHD warrants a definitive multiyear development program and adequate funding to progress toward commercialization at an early date.

As you are well aware, we have substantial problems to overcome before nuclear power becomes a continuing source of supply for our increased energy needs. This leaves our great coal reserves as the one reliable source of internally generated energy. It is clear that that coal must assume an increasing part of our national fuel mix. Yet, without any MHD or some unforeseen exotic technology coal cannot be expected to assume its destiny in our energy mix.

Only with the massive gains in efficiency, economics, and environmental controls offered by MHD can coal play its assigned part in a shift from primary reliance on shrinking oil suppliers to our relatively abundant control reserve.

Outside our country, there are active research and development programs for MHD in the Soviet Union, Poland, Yugoslavia, India, China, Netherlands, Australia, and Japan. The Japanese, in addition to their own program, have expressed an active interest from time to time in possible participation with the United States in the development of a sound MHD program.

If we do not pursue MHD research in this country, we may one day be buying this technology from other nations and I think that would be a mistake.

Utilities are more interested today than ever before and rightfully so in MHD for MHD is the only technology that has been meeting its milestones timely and successfully, and I have enumerated in my statement those milestones.

If MHD is to prove its commercial viability, an integrated proof of concept facility is needed. How do we get there? The major consensus is that the quickest and cheapest way is to couple a MHD plant to a conventional coal-fired plant and the Montana Power Co. has made an unsolicited offer to DOE to have one of our plants used for that purpose.

A multiyear program directed to approve of concept facility is essential if MHD is to come to fruition.

The Department of Energy's 1985 MHD budget request does have dollars for MHD in a multiyear program. Both are meaningful steps toward developing MHD. This is the first time this administration has recommended any dollars for this process.

I am concerned that the program currently proposed does not meet the goals required to enlist strong industry participation.

If the utilities and supporting industries are given an opportunity to comment and provide input to this DOE program, a most logical and efficient program can be developed. The Department has expressed a willingness to do this and is currently scheduling initial meetings with both the utilities and industry suppliers.

The research needed is that which will support the engineering scale-up required at this stage of MHD technology.

I believe the Government and Congress also needs to demonstrate its commitment to a multiyear cost-shared program and its reliability as a responsible partner with the utilities and industry to generate sufficient participation.

The MHD budget for 1985 should be in the range of what you have had in the last 2 years of $30 million to $40 million and it should have a sustainable program of that level for 4 or 5 years. It has been suggested in Senate bill 1278 and H.R. 4392.

I strongly recommend that these provisions be considered in structuring the DOE program. Commitment to a multiyear program can produce results if Congress makes the commitment through the authorization legislation whose long-term promise transcends parochial interest.

MHD offers our Nation, its utility customers, and its utilities exceptional opportunities to replace dwindling oil reserves with coal in our total energy mix; to conserve of our lone and abundant energy resource to make the most efficient use of the coal, to burn the coal in the most environmentally acceptable, efficient manner, to facilitate the ability of utilities to meet national energy goals, and to offer users of the electricity hope of a genuine progress being made in combating the escalation of the prices of the energy form.

I believe continued support for MHD is an imperative part of our national interest.

I appreciate the opportunity to make this statement.

[The prepared statement of Mr. McElwain follows:]

Testimony of Joseph A. McElwain,
Chairman of the Board, The Montana Power Company

before the

Subcommittee on Energy Development and Applications
of the House Committee on Science and Technology

March 8, 1984

My name is Joseph A. McElwain. I am chairman of the board of the Montana Power Company. Montana Power Company is an energy company which serves as an electric and gas utility to the western two-thirds of Montana. In terms of the area served, the Montana Power Company is the second largest operating utility in the United States. We also have major coal mining operations in Montana, Wyoming and Texas that are under Montana Power Company's wholly-owned subsidiary, Western Energy Company. Western Energy, last year, mined approximately ten million tons of coal and by the late 1980's will be mining approximately twenty-four million tons of coal a year in the three states it currently operates in.

I am deeply appreciative of the opportunity you have afforded me to testify in favor of continued and adequate funding of the Department of Energy program for development of the coal-fired magnetohydrodynamics (MHD) technology.

Montana Power Company and Western Energy Company have been early pioneers of the conversion of coal to energy through the MHD process.

As an electric utility which relies upon coal for its major base load, we are strongly interested in the efficient utilization of our coal resources.

Since 1973 when we in the United States got the signal of our vulnerability to dependence upon foreign sources of energy during the Arab embargo, the Montana Power Company has been a strong advocate of internalizing our energy capability through the greater utilization of our vast coal resources. The

United States possesses over 35% of the known coal reserves of the world, some 450 billion tons. The states of Montana, Wyoming and North Dakota possess approximately 45% of that coal reserve, with Montana having approximately 120 billion tons.

If we are to truly attack the problem of energy vulnerability, we must do everything possible to utilize these vast coal reserves.

It is for this reason that we in Montana have become great advocates of the MHD conversion process. As a utility executive, I simply cannot be satisfied with the present conversion factor of coal to electricity of approximately 30 to 35% efficiency. This is particularly true when there is a technology such as MHD which offers an ability to increase that efficiency to 45 to 55%. The commercialization of this process, in my judgment, represents one of the greatest contributions that can be made to efficient utilization of our coal resources, as well as making good conservation sense. If we can raise our utilization factor of coal by even 50%, this makes a great contribution to not only our energy source supply, but also to the capability of transporting coal to its place of use because every ton of coal shipped, if MHD is commercialized, would render 50 to 75% more energy than it currently does.

MHD presents the only technology for the direct conversion of coal to electricity on the scene today that increases efficiency as well as meets environmental standards and goals.

MHD is a relatively simple conversion process which moves a hot conductive gas through a strong magnetic field which then causes current to flow in the gas. There are no moving parts which should allow the process to run for sustained periods of time. MHD has the highest potential efficiency of all the new coal-burning technologies; its combustion process inherently controls

$SO_x$ and $NO_x$. The impacts of burning coal 50% more efficiently have tremendous benefits in reducing related environmental impacts through less mining, less transportation, less effluents. There are no technological break-throughs required to proceed with this promising conversion process. We are at the point where we need to prove its efficiency, economics and commercialization of scale. With all this potential and the possibility of lower cost electricity, I believe MHD warrants a definitive multi-year development program at adequate funding to progress toward commercialization at an early date.

As you are well aware, we have substantial problems to overcome before nuclear power becomes a continuing source of supply for our increased energy needs. This leaves our great coal reserve as the one reliable source of internally generated energy.

It is clear that coal must assume an increasing part of our national fuel mix. We all know how the coal window has enlarged versus the previously perceived nuclear option. But we have not been moving with dispatch in this critical area. In 1974, coal accounted for about 44% of the energy utilities employed to produce electricity. In 1980, that figure had grown by only 6 percentage points -- to only 50% -- while the consumption of electricity had leaped 19%.

Looking just a few years into the future, the best forecasts indicate the demand for electricity will escalate 114% by the turn of the century because electricity is that blessedly versatile form of energy that can serve many needs. Coal could and should be used to generate more than 2/3 of our total electricity, assuming attractive economics and superior technology.

Yet without MHD or some unforeseen exotic technology, coal cannot be expected to assume its destiny in our energy mix. Only with the massive gains in efficiency, economics and environmental control offered by MHD can coal play its assigned part in the shift from primary reliance on shrinking oil suppliers to our relatively abundant coal reserve. Prolonging the life of our coal supply through the efficiencies of MHD suggests that we should follow a course that will bring about expeditious application of the promising technology.

Outside our country, there are active research and development programs for MHD in the Soviet Union, Poland, Yugoslavia, India, China, Netherlands, Australia and Japan. The Japanese, in addition to their own program, have expressed an active interest in possible participation with the United States in development of MHD. Can all of these nations, as well as many of our own scientists, be wrong about the potential of MHD? I postulate that if we do not pursue MHD research, we may one day be buying this technology from other nations. However, today we are the leaders in coal burning-MHD technology and in just a few years its viability can be proven.

The utilities are more interested today than ever before and rightfully so, for MHD is the only technology that has been meeting its milestones successfully. The dollars spent have brought significant advances in recent years in areas which at one time were considered show stoppers.

1) Channel life - has gone from seconds to minutes to 1300 hours testing and an extrapolated life of 8000 hours.

2) A 4800° F coal combustor has been successfully developed and tested by TRW at the 20 $MW_t$ level and 90% slag rejection; with testing of a 50 $MW_t$ level combustor underway.

3) High temperature air heaters have not been successful. The near term alternative is use of oxygen air enrichment at a 3 to 4% efficiency loss, while development continues.

4) Steam Bottoming Data is encouraging - Argonne National Lab has successfully used soot blowers to strip MHD-type ash from tubes and CFFF tests on $SO_x$ and $NO_x$ are well below EPA limits.

5) A super conducting magnet of 6.2 Telsa has been built and tested at Argonne National Laboratory.

6) A successful DC-AC inverter was developed by the Electric Power Research Institute and installed at the CDIF.

7) Spinoffs have occurred - atmospheric slag rejecting coal combustors - low $NO_x$ combustors - high temperature heat exchangers - hot gas (plasma) research, etc.

The MHD Users Group made up of 26 member electric utilities comprises the Edison Electric MHD Task Force. This group represents the major utilities of the United States using fossil fuels. The utility industry complex is represented by the MHD Industrial Forum which includes utilities, utility component manufacturers, suppliers and engineering, design and construction firms. Several have no government MHD contracts, but see the potential of the technology.

All this is encouraging, but if MHD is to prove its commercial viability, an integrated proof of concept facility is needed. How do we get there? The major concensus is that the quickest and cheapest is to couple an MHD plant to a conventional coal-fired plant. A multi-year program, directed to a proof of concept facility, is essential if MHD is to come to fruition.

The Department of Energy's 1985 MHD budget request does have dollars for MHD and is a multi-year program. Both are very meaningful steps toward developing MHD. I am concerned that the program currently proposed does not meet the goals required to enlist strong industry participation. If the utilities and supporting industries are given the opportunity to comment and provide input to this DOE program, I believe a most logical and efficient program can be developed. The Department of Energy has expressed a willingness to do this and is currently scheduling initial meetings with both the utilities and industry suppliers.

Two of my major concerns with the proposed DOE program are:

1) The 80 megawatt thermal system is too small. The utility industry in the study completed for the State of Montana Department of Natural Resources and Conservation outlines a set of qualitative performance requirements which must be met before the utility industry could, with reasonable expectations, proceed with commercialization of the technology. Serious thought must be given to building a system large enough to address the varying levels of scale-up risk for the different components. The system must be large enough to provide confidence in extrapolation of the data to a commercial sized unit to the utility suppliers as well as the utilities. This confidence is necessary to establish the very important Industrial Base. The recent Congress requested study "Magnetohydrodynamics (MHD) Program Evaluation," May 5, 1983, by Gilbert/Commonwealth for DOE also recommends larger proof of concept plants, preferably as an add-on to a commercial steam plant. Montana Power Company has made an offer to participate with the government in such a retrofit. While some additional risks are involved to go from the present scale of testing to the larger facility, the resulting reduction in the testing program, in overall program costs, development time, and addressing scale-up questions in the development

stage, would seem to justify those risks. The concept of an integrated system test is strongly supported by the utility industry. If a test at the 80 megawatt thermal level is an intermediate stage in an R&D program, there may be some justification for this additional step, however, as an end to the government program it will not meet the needs of the utilities, nor meet the government's goal of developing an adequate data base that will enable private industry to apply the technology commercially.

2) I believe the proposed funding of the 1984-85 budget is insufficient to accomplish the stated goals. The dollars are not sufficient to carry on a research and development program toward a significant proof of concept facility. The industry has contributed substantially in the past, but the proposed percentage of participation in cost-share is optimistic for a technology at this stage in its development and facing the very real risks involved in scale-up. In addition, the funds for the Phase I scientific research program appear to be applied to basic research activities which were the focus of the program in the early 1970's. The research needed is that which will support the engineering scale-up required at this stage of MHD technology development. If the Phase II integrated system is pursued at a scale larger than 80 $MW_t$, the current government test facilities could be used to generate the data necessary to design the larger sized components. Furthermore, the program, as outlined, does not take advantage of cost savings to the program which might be achieved through cooperative technical and financial exchange with other foreign MHD development programs. I believe the government and Congress

also needs to demonstrate its commitment to a multi-year cost shared program and its reliability as a responsible partner with the utilities and industry to generate sufficient participation. The MHD budget for 1985 should be in the 30 to 40 million dollar range for MHD to make progress.

My evaluation is that the budget program is a start in the right direction, and I am delighted to see a reversal of position in the Department of Energy. However, I believe the current MHD technology is to a point where we need to outline a multi-year program to reach a point where its commercial and economic viability will have been demonstrated. The concepts contained in S. 1278 or H.R. 4392 provide the more complete multi-year program to bring the MHD technology to the point it can be put into use in the utility industry. I strongly recommend that these provisions be considered in structuring the DOE program. Commitment to a multi-year program can produce results if Congress makes the commitment through authorizing legislation whose long-term promise transcends parochial interests and the immediate federal commitment to a broad range of budgetary stringencies. MHD offers our nation, its utility customers and its utilities exceptional opportunities to replace dwindling oil reserves with coal in our total energy mix; to conserve our lone abundant energy resource by making the most efficient possible use of coal; to burn coal in the most environmentally acceptable, efficient manner; to facilitate the ability of utilities to meet national energy goals, and to offer the user of electricity hope of genuine progress being made in combating the escalation of the price of that energy form. I believe continued support for MHD is an imperative in the context of the national interest. Thank you for your attention and consideration.

Mr. **Boucher** [presiding]. Mr. Hart.

Mr. **Hart**. I appreciate very much the opportunity to testify today in support of the Wilsonville Advanced Coal Liquefaction Research and Development Facility and to request the addition of approximately $7.5 million to the Department of Energy's fossil energy budget for fiscal year 1985 to continue operation of this very important pilot plant. Responsibility for the present contract with the U.S. Department of Energy for Wilsonville resides in my department in Southern Company Services.

The Department of Energy and the Electric Power Research Institute provide funding for the operation of Wilsonville. Southern Company Services is the prime contractor to both of these organizations, and Catalytic, Inc., is our subcontractor for operation of the pilot plant. The annual operating budget is approximately $9.5 million.

I have prepared formal testimony which has been submitted in accordance with instructions from your staff. I hope that each member of this distinguished committee will have the opportunity to read this six-page statement which discusses in detail the justification for continuation of Wilsonville.

Some of the key strategic issues which we emphasize are:

The United States continues to be vulnerable to a major disruption of present imported oil supplies and thus needs the capability to produce substitute liquid fuels from coal.

The Wilsonville facility is the only remaining pilot plant dedicated to coal liquefaction research which is presently capable of continuing the development of advanced liquefaction technology.

Other countries are involved in major programs to advance their capability of producing coal-derived liquids in order to reduce dependence on imported oil.

The most important reason to develop the technology for producing coal-derived liquids is to have that technology available when the supplies of petroleum at acceptable prices do not meet the Nation's needs. Also, it is important to note that the use of coal-derived fuels could have a beneficial effect on the environment. The average sulfur content of crude oil is increasing. Coal-derived liquids are lower in sulfur than many of the lower quality petroleum-based residual fuel oils being used by utilities today.

Recent activities at the Wilsonville pilot plant have focused on the development of advanced two-stage liquefaction process technology. With two-stage liquefaction, up to 90 percent of the products can be utility fuel products: either distillates to replace No. 2 fuel oil, heavy liquids to replace No. 6 fuel oil, or solids containing no ash and about 0.2 weight percent sulfur. Recent experience at Wilsonville has shown that integrated two-stage liquefaction can convert approximately 60 weight percent of the coal into clean liquid fuels.

In evaluating the merits of continuing the Wilsonville program, the following points are emphasized in the testimony:

The accomplishments and capabilities of Wilsonville are significant.

The program objectives are dedicated to the advancement of two-stage liquefaction technology for production of liquid boiler fuels from coals and the development of a data base and model to support commercialization of the two-stage liquefaction process.

Previous research at Wilsonville and other coal liquefaction projects has identified those direct liquefaction processes which offer the best potential for commercialization. Development of unit process models will provide better understanding of two-stage liquefaction and will provide a basis for scale-up.

Wilsonville is an outstanding example of successful joint research sponsorship by Government and the private sector. The approximate amount of funds provided by the participants through 1983 were $41 million by the Government and $35.3 million by the private sector.

If the program is terminated before completing a model for commercialization, most of the benefits from this investment will be lost. The Electric Power Research Institute has already approved $3.5 million per year for 1984 and 1985 to continue its share of this project. Southern Co. Services is committed to continue to provide project management at no cost to the Department of Energy and the Electric Power Research Institute.

In addition, we have a highly trained and capable technical and management organization which provides a firm capability for assessing the potential of two-stage liquefaction technology. Current programs which are planned through 1986 would advance this technology to a state of readiness for commercial application which could have very large benefits in the event of disruptions to current oil supplies.

In other words, we consider this to be a very important insurance policy in our energy supply picture.

Finally, I should point out that the request for continuation of the Wilsonville program is not motivated by self-interest for the Southern Co. since less than 1 percent of our generation in 1983 was produced from burning oil. Our strong motivation is in support of electric utilities who have substantial oil-fired generation and, more important, because we think it is in the national interest to have a proven coal liquefaction technology ready for commercialization.

I would remind you that approximately 20 percent of the total electric-generating capacity in the United States is oil-fired and thus vulnerable to cutoffs of imported oil supplies. A recent Electric Power Research Institute study projected that utility industry consumption of fuel oil will stabilize at about 600,000 barrels per day for the foreseeable future. This would appear to offer an attractive market for coal-derived liquids.

However, we must remember that the price of crude oil is not determined by the cost of production or by the normal economics of supply and demand. Crude oil and its pricing are political tools and the risks caused by the political use of crude oil supply are too great for industry to undertake the development of alternative technologies alone.

I thank you for your attention and respectfully request that you consider the merits of this proposal and weigh the very real benefits which can be derived from continuation of the coal liquefaction research program at Wilsonville.

[The prepared statement of Mr. Hart follows:]

## PREPARED STATEMENT OF S.R. HART, JR., SOUTHERN COMPANY SERVICES, INC.

The Wilsonville Advanced Coal Liquefaction
Research and Development Facility
March 1984

### Introduction

Thank you. My name is S. R. Hart, Jr. I am Vice President, Research and Development of Southern Company Services, Inc. (SCS) Birmingham, Alabama. Responsibility for the present contract with the U.S. Department of Energy (DOE) Contract Number DE-AC22-82PC50041 for operation of the Wilsonville Advanced Coal Liquefaction Research and Development Facility resides in my department in SCS.

The purpose of my testimony today is to justify the continued operation of the Wilsonville facility through completion of the presently planned program and to request funding of approximately $7.5 million for Wilsonville in the DOE Fossil Energy Budget for FY'85. In support of this request, this testimony presents information about the Wilsonville facility and its role in developing the solvent refined coal (SRC) process. The objectives, accomplishments, and capabilities of the facility and the rationale for the continuation of its program are presented. For background, an overview of the need for coal liquefaction technology and the status of technology development is also presented.

### Summary

The Wilsonville Advanced Coal Liquefaction Research and Development Facility has made a significant contribution to advancing coal liquefaction technology. Current programs which are planned through 1986 would advance this technology to a state of readiness for commercial application which could have very large benefits in the event of disruptions to current oil supplies. Although meaningful research on coal liquefaction could continue at Wilsonville beyond 1986, it appears that the major objectives can be reached by the end of 1986. Therefore, unless there is a drastic change in the nation's outlook for oil or redirection from DOE and the Electric Power Research Institute (EPRI), the plans for Wilsonville will include completion of the important work currently underway followed by an orderly shutdown of the facility at the end of 1986.

### Need for Coal Liquefaction Technology

A study released by the Congressional Research Service in September 1983, estimated the effects of a one-year cutoff of Persian Gulf oil supplies. That study estimated that such a cutoff in 1982 would have caused the world price of crude oil to increase from $34 per barrel to the range of $66-to-130 per barrel, depending upon the price elasticity of demand for oil. Other analysts have estimated that closing the Strait of Hormoz in the Persian Gulf could cause a shortfall of up to 8.5 million barrels per day and an increase in the price of crude oil to $100 per barrel.

Although the recession, conservation, and other factors had reduced United States crude oil imports to about 3.3 million barrels per day in early 1983, increasing demand caused imports to increase to nearly six million barrels per day during August and September of 1983. At a price of $29 per barrel, these imports cost more than $60 billion per year. However, the New York Times reported on December 8, 1983 that "The Reagan Administration has announced that it is no longer the goal of the United States to work toward independence from Arab oil imports."

The price of crude oil is not determined by the cost of production or by the normal economics of supply and demand. Crude oil and its pricing are political tools and the risks caused by the political use of crude oil supply are too great for industry to undertake the development of alternatives alone.

The present price of crude oil makes petroleum less expensive than coal-derived liquids. However, as noted above, the loss of Persian Gulf oil supplies could cause the price of crude oil to double or triple in a few months. The finite and limited reserves of petroleum insure that the price of oil will increase eventually.

Liquefaction of coal will become economically attractive in the United States when the price of crude oil increases significantly above the present level. This could result from a sudden loss of imported oil at any time, or from the more gradual depletion of world oil resources. There are no good estimates of when crude oil will cost more than coal-derived liquids. However, present estimates indicate that the cost of coal-derived liquids in the near future would be about $45 per barrel, or approximately 50 percent above the present price of crude oil. In view of the 800 percent increase in the price of oil since 1973, it is apparent that additional increases in the price of oil which would make coal-derived liquids economically attractive could occur in a short period of time. The availability of alternate fuels, including coal-derived liquids, can put a ceiling on the price of oil. The development of coal liquefaction technology should be continued so that the technical risks of building commercial plants can be reduced and so that the technology will be ready for rapid utilization when needed.

A recent report by the National Research Council urges the Department of Defense to build a facility to produce synthetic fuels. That report indicates that shortages of synthetic fuels may delay the development and testing of new jet engines for the Department of Defense. The availability of alternatives to petroleum is important to both the economic and military security of this nation.

The most important reason to develop the technology for producing coal-derived liquids is to have that technology available when the supplies of petroleum at acceptable prices do not meet the nation's needs. However, it is also important to note that the use of coal-derived fuels could have a beneficial effect on the environment. The average sulfur content of crude oil is increasing. Coal-derived liquids are lower in sulfur than many of the lower quality petroleum-based residual fuel oils being used by utilities today.

## Status of Technology Development

Research and development of coal liquefaction technologies accelerated rapidly after the 1973 oil crisis. An ambitious program to build large pilot plants and demonstration plants was started. The present administration has expressed a different view of the federal role in synthetic fuels and wants to limit federal activities to small-scale research and development on high risk technologies. The attitude of the present administration, the worldwide recession, and the resulting stabilized oil prices, have caused most synthetic fuels projects in the United States to be abandoned. The large pilot plants for the Exxon Donor Solvent process, the H-Coal process, and the SRC-II process have been shut down and dismantled. For practical purposes the demonstration plant program is dead.

The attitude of the present administration toward development of alternative fuels technology to reduce United States dependence on imported oil is not shared by other nations.

The Japanese government has been carrying out work on the technical development of coal liquefaction and gasification since 1980. The New Energy Development Organization (NEDO) is a Japanese governmental body which is supported by both the Japanese government and Japanese industry. A NEDO report dated March 1983 states that although the adequate supplies of oil at stabilized prices have given some immediate relief, they believe that they should proceed with the development of technology as before. The NEDO report reaffirmed the belief "that the development of alternative energy sources is a means of solving the restrictions on energy use." There seems to be a strong Japanese commitment to a program which is seen to require at least ten years for completion. NEDO is working closely with Australian industries and obviously has the strong support of several Australian governmental bodies.

The recent decreases in energy prices apparently will not keep the European Community (EC) from its long-term goal of cutting dependence on imported oil by diversifying its energy sources. A five-year energy plan recently put forth by the EC Commissions reflected a continuing commitment to that goal.

Government and industry in South Africa continue to utilize and develop coal liquefaction technology. There, the SASOL II and SASOL III complexes produce over 70,000 barrels per day of gasoline and diesel fuel from coal. This is more than half of that nation's supply of motor fuel. The indirect liquefaction technology used by SASOL would not be economically viable in the United States. However, the low cost of coal, lack of domestic petroleum resources, and unique political factors do make it attractive in South Africa, where energy self-sufficiency seems to be an achievable goal.

## Wilsonville Accomplishments and Capabilities

The Wilsonville facility consists of three major process areas. The thermal reactor unit with a design capacity of six tons of coal per day began operating with coal in 1974. The Kerr-McGee Critical Solvent Deashing unit was installed and started up in 1978. The hydrotreater unit (second stage ebullated bed catalytic reactor) began operating in 1981. The facility also has laboratories, a data acquisition system, and a state-of-the-art wastewater treatment system.

The Edison Electric Institute (EEI) and The Southern Company system began a joint pilot plant project to study the key steps in the solvent refining of coal in March 1972. The thermal reactor unit at Wilsonville, Alabama, was completed in late 1973. EPRI assumed the responsibilities for utility industry project participation from EEI in April 1973. The U.S. Energy Research and Development Administration (ERDA), now DOE, joined EPRI as a joint sponsor of pilot plant operations in 1976. Southern Company Services, Inc. (SCS) provides overall project management at no cost to DOE and EPRI. The approximate amounts of funds provided by the participants through 1983 were ERDA-DOE, $41 million; EEI-EPRI, $30 million; and The Southern Company system, $5.3 million.

The Wilsonville facility has become a unique national asset in that it has the broadest capability of any liquefaction pilot plant in the United States, is open for the testing of proprietary technology developed by others at a meaningful scale, and produces sufficient quantities of products for small-scale combustion testing and product upgrading research. The project has consistently run within budget and without significant cost overruns.

Recent activities at the Wilsonville pilot plant have focused on the development of advanced two-stage liquefaction process technology. With two-stage liquefaction, up to 90 percent of the products can be utility fuel products: either distillates to replace No. 2 fuel oil, heavy liquids to replace No. 6 fuel oil, or solids containing no ash and about 0.2 weight percent sulfur.

Recent experience at Wilsonville has shown that integrated two-stage liquefaction (ITSL) can convert approximately 60 weight percent of the coal into clean liquid fuels. Previous work at Wilsonville demonstrated that nonintegrated two-stage liquefaction produces a significant yield of middle and heavy distillate as well as either low sulfur solid fuel or No. 6 fuel oil substitute. Some significant accomplishments include the following.

- Demonstrated that integrated two-stage liquefaction can convert approximately 60 percent of coal to distillate fuels (1983)
- Demonstrated that nonintegrated two-stage liquefaction can produce a fuel that can directly replace No. 6 fuel oil for utility applications (1982)
- Provided design data for the 6000 tons per day SRC-I Demonstration Plant Project (1978-1982)
- Improved mechanical performance of pumps and valves by design changes and material selection (1974-1983)
- Proved that the SRC process can be operated in solvent balance for extended periods of time (1980-1981)
- Demonstrated operation of a state-of-the-art waste water treatment system (1979-1983)
- Developed a mathematical model to predict residual coal conversion in the second (catalytic) stage of two-stage liquefaction (1982-1983)

## Program Objectives

There are two major reasons for continuing the Wilsonville program. These are (1) to improve the fundamental understanding of the mechanism of direct coal liquefaction and (2) to develop data that can be used by industry to build commercial plants when economics permit. The second reason is the most important because the Wilsonville facility is the only existing pilot plant that can provide such data.

The primary program objective for advanced coal liquefaction process development is to demonstrate the production of environmentally acceptable liquid and solid fuels from coal at costs that would be acceptable to electric utilities and other industries. The purpose of the research is to advance the technology of multi-stage liquefaction through an ordered research program which examines the individual components of the ITSL process. This will provide the data necessary for an integrated process model, which is needed for process scale-up and design.

Previous research at Wilsonville and other coal liquefaction projects has identified those direct liquefaction processes which offer the best potential for commercialization. Development of unit process models will provide better understanding of two-stage liquefaction and will provide a basis for scale-up. Variability studies will be conducted at each of the three process units. Data from these studies will be used to develop the unit process models. The planned program would complete the modeling work by the end of 1986. During 1984 and 1985 a model for the thermal reactor unit, the most complex (from a kinetic viewpoint) and least understood part of the process, will be completed. In 1986 the effect of coal rank on process performance will be determined.

Completion of the program should produce sufficient data to allow industry to scale-up the most important two-stage liquefaction processes to commercial size and to determine the most economical process for any given product slate. If the program is ended before the program goals have been completed, the data obtained to date will lose a significant part of their value.

## Funding Status

The current contract for operating the Wilsonville pilot plant expires on December 31, 1984. The contract contains an unfunded option to continue operation for an additional year. The level of effort will continue at the same level as the previous two years because of limited funds from DOE. It had been recommended that the level of effort be increased because of the more complex process development and because other support programs have been eliminated. Funding for the 11-month contract period from February 1 through December 31, 1984 is $8,794,124 for operating costs and $905,876 for capital costs. DOE is providing $6.5 million to cover part of the operating costs and EPRI is providing $3.2 million to cover the remainder of the operating costs and all of the capital costs. EPRI has approved $3.5 million for Wilsonville in their CY'85 budget and the staff has indicated that they would like to support Wilsonville in CY'86 if DOE is willing to continue support. Additional funds will need to be appropriated by Congress for FY'85 to cover the option year in the contract. Current estimates indicate that about $10 million ($7.5 million in FY'85 and $2.5 million in FY'86) will be needed from DOE to cover the option year in the current contract. This level of funding is more than in the current contract but will bring the level of effort up to point believed necessary to produce the most useful data. As discussed previously in the section on program objectives, it is very important that a commitment be made to continue the project for two years beyond December 31, 1984, to complete the objectives that have been set. The type of objectives that have been set have very little value if they are not completed.

## Other Possible Uses for the Wilsonville Facility

The three major areas at the Wilsonville facility are the thermal reaction area, the critical solvent deashing area, and the hydrotreater area. These three areas were studied to determine whether the variety of chemical processing equipment in each area could be effectively used for other research activities. The thermal reaction area can process a total of approximately one ton per hour of feedstock at temperatures up to 850°F and pressures up to 2800 pounds per square inch. The Kerr-McGee Critical Solvent Deashing (CSD) unit at Wilsonville is the only pilot scale unit for this deashing technology. The unit is owned by the Kerr-McGee Corporation and operating conditions are proprietary. The hydrotreater area contains an ebullated bed hydrotreater reactor and related equipment which are suitable for service at 850°F and 3,500 pounds per square inch.

The Wilsonville facility obviously could be used for work on other direct coal liquefaction processes as the equipment is suitable for use at the conditions required for most direct liquefaction processes. The facility is versatile and could be readily adapted for work on a variety of processes. The equipment is the same as, or very similar to that used in petroleum processing. The facility could be used for work on many processes related to petroleum, shale oil, and products from tar sands and the pyrolysis of coal. SCS would be pleased to consider proposals for work in these areas beyond 1986 if there is sufficient justification.

sam:0040f

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Mr. **Boucher**. Thank you, Mr. Hart.

I want to thank all of the witnesses for their carefully considered and well-presented testimony here today. I am going to have to answer a call of the House. I would hope that each of the witnesses could remain. We do have a number of questions that I would like to pursue with you, but it is going to be about 15 minutes before I can return.

So, the committee will be in recess for 15 minutes.

[Recess.]

Mr. **Boucher** [presiding]. The committee will come to order. Mr. Schora, you have requested $1 million for the Eastern Shale Resource Assessment. Can you tell us what the extent of that assessment is to date?

Mr. **Schora**. With the number of people that have looked at it, the one I am most familiar with is the assessment conducted by IGT, basing its basis on shale which is within 300 feet of the surface in its various States, and looking at utilizing the hydroretorting technology which gives the high yield, we are talking about the order of 400 billion barrels of oil.

This is equivalent to about 10 million barrels per day for the next 100 years, so it is a very significant resource.

Mr. **Boucher**. What would the States be able to accomplish with these funds that you are requesting?

Mr. **Schora**. To better identify those areas in the States in which an industry could be founded where the maximum yield could be realized at the minimum insult to the environment.

Mr. **Boucher**. Identify the characteristics distinguished between eastern oil shales and western oil shales.

Mr. **Schora**. The characteristics of the eastern shales, which are more similar to oil shales throughout the world than are the western shales, is that the eastern type shale is somewhat deficient in hydrogen, when one looks at the hydrogen-to-carbon ratio in the organic material, and because of this technology utilized in the thermal processes in the west tend to produce coke rather than oil.

When one retorts in the presence of hydrogen, then the coke is suppressed and you get much more oil as a product, so they are uniquely different shales.

Mr. **Boucher**. Are the same extracting processes applicable to both western and eastern oil shales?

Mr. **Schora**. Decidently not, although the western processes can be utilized on eastern shale, you don't realize the yields, for the quality of oil that you can get with the newer technology.

Mr. **Boucher**. What are the extracting processes that you would recommend for eastern shales?

Mr. **Schora**. The processes that are being looked at today for eastern shales is one we have been involved with for a number of years, and that is basically the treating of the shale in the presence of hydrogen retorting.

Thermally processing the shale in the presence of hydrogen rather than inert gases, and it suppresses coke formation, increases oil yield.

Some people are working on the concept of retorting in the presence of steam with very fast heating rates, and other people are looking at the retorting of shale very rapidly, again, with hydrogen.

Mr. BOUCHER. Are those technologies more expensive to implement than are the technologies for extracting western oil shales?

Mr. SCHORA. Based on studies done by an engineering firm where they compared basically the high tort process, hydrotorting versus conventional thermal retorting for western shales, that study indicated that actually the overall investment for the plan was less for the hydrotorting, because less shale was processed, and it is the expense of handling the shale which adds to the price of these plans.

Mr. BOUCHER. Could you explain to us what work would be done with the $6 million that you are requesting for processing work related to eastern shales?

Mr. SCHORA. Basically, it is to enhance and enlarge the data base to better understand the function of hydrogen in the retorting process with the objective of minimizing the consumption of hydrogen, and basically maximizing the yield of oil for a minimum cost.

One other area that we have been quite interested in, we have been doing some work with the people in Alabama, is a prebeneficiation step to take out most of the rocky material, and thereby also furthering the reduction of potential cost, this would then bring other States, possibly West Virginia, in this potential shale resource basis.

Mr. BOUCHER. What environmental issues are unique to eastern shales that would require a $2 million program?

Mr. SCHORA. Some of the environmental questions that certain of the States have certainly is the leachability of the possible metals, and other constituents in the spent shale, as it might affect ground water supply, the potential of the possible activation of the sulfur in the spent shale, and basically studies of capping the spent shale after it is recommitted to the ground, to avoid this kind of pollutant.

The eastern shales tend to be much more stable than the western shales, because they are not a caustic-based shale, and they are a silicon-based shale, and you don't get the very caustic problem when water reaches the shale after retorting.

Mr. BOUCHER. Thank you.

Mr. McElwain, a few questions for you. What, in your opinion, are the major technical roadblocks to developing MHD as a source for electricity generation?

Mr. MCELWAIN. I believe my testimony indicates that there are no technical roadblocks left. The one place I point out is that using oxygen versus the reheater is something that has to be, or air heater has to be solved yet, but that is not required for the technology.

I think the technology is there. I think where we are is that we have got all of the components developed in several different places, and now we need to put them together to have a MHD cycle that is put on top of a regular cycle to show the economies of it, to show the scale up of those components, and to show the efficiencies of the scaled-up model.

Mr. BOUCHER. How much longer do you think a Federal commitment to R&D for MHD is going to be necessary in order to make this process commerically feasible?

Mr. McElwain. If there is a 5-year commitment that the industry knew was there, that could be utilized with some facilities as I have indicated that we have made available for that purpose, I think a 5-year program of $50 million a year would prove out, with the industry participation, prove the process out.

Mr. Boucher. Is that 5 years prospectively, or is that including past years?

Mr. McElwain. Five years prospectively.

Mr. Boucher. Are there any utilities today that have expressed an interest in participating in the commercial development of MHD?

Mr. McElwain. I think that the utility industry today is much farther along in embracing MHD than they ever have been in the past. They have an EEI Task Force, made up of some 26 utilities that represents about 85 percent of the coal burning in the United States, so that there is a major interest in it, that I think it does take at this juncture a substantial Federal commitment, I think, to get to a commercialization stage.

But I am sure you would find participation interest by a great number of utilities.

Mr. Boucher. I would like to ask you to be a little more precise concerning that very point. To what extent do you think private utilities are willing to enter into cost-sharing arrangements with the Federal Government and utilize the process?

Mr. McElwain. I can speak only for my company. We have made a commitment that we would furnish the bottoming cycle of either a 180-megawatt coal-fired unit that we now have at Billings, MT, or a 60,000-kilowatt coal-fired unit, or a gas-fired unit which would be the bottoming cycle, and the basis for proving the process, depending upon the scale you went.

I think that Southern California Edison has made some commitments of a preliminary nature on retrofiting some of their gas-fired units with MHD. I believe that there would be a commitment made as of this time for EPRI participation to some level in moving this process forward.

Mr. Boucher. What do you think the proper mix in public-private funding will be for the balance of the 5-year period necessary to obtain commercialization of the technology?

Mr. McElwain. Oh, I would like to see that there was a commitment on the part of the Federal Government to really go forward with this program. The Congress has been very insistent over the last 2 years in the face of a recommendation by the administration to phase out this program.

I think that if there was a commitment in the range of $30 to $40 million by the Federal Government over an extended period of time, you would find the rest available. I am speaking just for our company and I am not representing anybody else at this juncture.

Mr. Boucher. I seem to be getting messages from three different sources here at once. Why, in your opinion, is the 80-megawatt thermal system which DOE has suggested too small, as indicated in your prepared statement?

Mr. McElwain. I think it does not—two things wrong with it.

I think it envisions an integrated system that has a bottoming cycle as well as a topping cycle and to me, I am speaking as a lawyer now, not as an expert, but to me where you have got a facility that can be utilized and converted for that, to spend that money on a bottoming cycle makes no sense to me.

Mr. BOUCHER. What size would you suggest?

Mr. MCELWAIN. I would suggest taking a look, if they are not satisfied with 180 megawatts, with maybe 50-megawatt topping cycle on it, that looked to the 60-megawatt gas-fired unit that we have said we would make available and scale the topping cycle to conform to that magnitude, and I guess I don't have it right in my head what the amount of the topping cycle would be on that, but it would be substantially more than the 20 megawatts of electric that is involved in the present one.

We need a larger scale size to really make sure that the economies are there and the efficiencies are there, and I think that 20-megawatt does not do that.

Mr. BOUCHER. You mentioned in your testimony that a number of other countries are presently supporting research efforts with regard to MHD. Ours, as I understand it, is directed toward the utilization of coal, as the source of the gas which is in turn electrified when passing through a magnetic field.

A number of the other countries, I am led to believe, are planning to use natural gas directly as the base component, am I right in that assumption?

Can you give me some indication of what other countries, if any, are focusing upon coal as the basic fuel?

Mr. MCELWAIN. Well, Russia is focusing on coal. We have their unit that is supposed to be under construction now, and to be of a magnitude of some 500 megawatts, is a gas-fired unit, but they also in their last symposiums that they have attended, have indicated, and one I attended 2 years ago, that their then-schedule was to have a 500-megawatt coal-fired unit on line by 1991.

I am sure that has slipped a couple of years because their gas-fired one has slipped.

Mr. BOUCHER. Gentlemen, I want to thank all of you very much for your testimony today. In view of the fact that we have another call of the House, I think I am going to exercise the prerogative of the Chair to adjourn the committee at this point.

We will probably be submitting questions in writing which are in addition to the questions that we have had orally today.

I thank you very much for being with us. The committee is now adjourned, subject to the call of the Chair.

[Whereupon, at 4:10 p.m., the subcommittee adjourned, subject to the call of the Chair.]

[Questions and answers submitted for the record follow:]

DON FUQUA (Fla.), Chairman

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April 9, 1984

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Dear Bernie:

Thank you for your testimony before the Subcommittee on Energy Development and Applications on March 8, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 30. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

DON FUQUA
Chairman

DF:Kcw
attachment

**IGT**
Headquarters

Bernard S. Lee, President
312/567-3741

April 25, 1984

The Honorable Don Fuqua
U. S. House of Representatives
Committee on Science and Technology
Suite 2321 Rayburn House Office Building
Washington, DC 20515

Dear Don:

Thank you for your letter of April 9. Attached please find the answers to the 8 additional questions raised by members of the Subcommittee. If further inputs are required, please let me know.

I appreciate the opportunity to testify before your Subcommittee this year and am grateful for the interest and support you have shown in the vital energy R&D programs.

With best regards.

Sincerely yours,

Bernie

Encl.

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Response to Questions (4-9-84) from Chairman Don Fuqua
Subcommittee on Energy Development and Applications

Q1. In your opinion, what size gasifiers are necessary to commercialize biomass gasification and when can we get to that size?

A. Biomass gasifiers should be modular in design to allow shop fabrication and ready replication. A typical pressurized commercial gasifier would range from 5- to 10-ft in diameter and process from 250-1000 tons per day of feed biomass on a dry basis. This range of feed rate fits well into the current logistics of collecting and transporting biomass feedstock. The route to commercialization should include:

(1) Completion of the studies in the existing 1-ft diameter PRU to establish the optimum design parameters for air- and oxygen-blown gasification over the range of commercially applicable pressures up to 30 atmospheres.

(2) Design, construction, and operation of a small commercial modular prototype about 5 feet in diameter.

(3) Further scale-up in the commercial sector to gasifiers up to 10 feet in diameter.

The overall time schedule, assuming adequate funding levels, will require 2-1/2 years to complete the PRU optimization, 2 years for design and construction of the prototype, and 2 years of prototype operation to confirm economic feasibility. Therefore, a highly versatile pressurized biomass gasifier can be ready for commercial deployment by early 1990.

Q. How much would demonstrations of that technology cost?

A. The PRU test program would cost $3 million for the 2-1/2 years. The design and construction of the prototype commercial facility would cost $12 million. The operation of that facility would cost $10 million for 2 years. Thus, a total of $25 million is needed to demonstrate a pressurized biomass gasifier system.

Q. Is there interest in industry co-funding of large-scale biomass gasifiers?

A. Yes. However, the requirements for co-funding for the commercial prototype should not be too stringent so as not to stifle the full development of the technology which has significant benefit for the national energy future.

Q2. In your opinion, can the relative economics of geopressured resources be determined in the next few years leading to the termination of expensive well drilling and operation, and to the concentration on smaller scale R&D activities? Why or why not?

A. No. Multiple years of production testing with appropriate instrumentation and laboratory support are still required to determine the relative economics of gas production from geopressured resources. The reason is that a large reduction in reservoir pressure must be achieved and then maintained so that we can obtain essential data on the variation of quantity and composition of produced hydrocarbons and on the reservoir drive mechanisms.

The DOE program has provided sufficient data to conclude that relative economics for production of brine that is not saturated with natural gas will not be favorable before the year 2000. At the same time, several of the tests have revealed that saturated reservoir brine was accompanied by a dispersed free-gas phase that is very encouraging in terms of potential economics. For such reservoirs, geological and engineering technologies for prediction of long-term production must be developed before relative economics can be determined and before private risk capital investment would be warranted.

What is needed is a combination of small-scale laboratory determination of the properties, under simulated conditions, of geopressured formations and actual field tests of wells, fully instrumented to obtain the complete spectrum of data. Constant feedback and interaction are absolutely essential between laboratory results which can be used to predict field results and the actual field data which permit refinement of the predictive models developed from the laboratory data. Concentrating only on small-scale R&D without the necessary field verification is incomplete.

To date, mechanical problems with the design wells have consumed budgeted funds and resulted in minimal data on the technical issues most relevant to natural gas production. To the extent that continuing trouble-free operation of existing design wells can be achieved with shifting emphasis to more scientific data collection, laboratory support and data interpretation, these wells should provide a cost-effective source of needed data and understanding. However, it is suggested that each well be abandoned if gas content of reservoir brine is below saturation or if the well encounters problems that will require expensive repair. Program emphasis should shift to lower cost wells-of-opportunity for the needed long-term tests.

Prior experience with DOE wells-of-opportunity suggests that conservative engineering and associated modest rate flow testing of wells drilled by industry, such as the Willis Hulen No. 1 Well, may well provide needed data and understanding for natural gas production with substantially lower cost than the large diameter wells designed to produce 40,000 barrels per day for thermal and hydraulic energy recovery. Important data relevant to these renewable energy forms would still be obtained.

The science of geopressured resources is still highly empirical. So much is unknown in the properties of the resources in place that expanded support must be provided for a decade before a reasonable predictive tool is available for commercial use. But the tremendous potential of geopressured energy resources must not be ignored and must be ascertained. To this end, funding level of at least $11 million per year is needed to support a coordinated program of both laboratory and field work.

Q3. What are the main problems that need to be overcome in molten carbonate fuel cells?

A. The problems in fuel cell development can be classified into two groups: technology-base-related and endurance-related. Endurance, or life expectancy, of fuel cells is specific to a particular design and stack fabrication technique and must be established by long-term testing of stacks principally by the manufacturers and users. Technology base, on the other hand, is generic and must be built by independent R&D groups whose results can be made available to the entire fuel cell community.

For the mature first-generation phosphoric acid fuel cell technology, the major emphasis should be on commercial manufacture and field testing of stack modules, with only minor emphasis placed on technology-base building. At the other extreme, for embryonic third-generation concepts, such as solid oxide fuel cell technology, the primary emphasis should be on technology-base building to stimulate the broadest spectrum of interest within the R&D community to solve the fundamental technical problems.

The second-generation molten carbonate fuel cell logically lies between these two extremes. It has been developed sufficiently to require both technology-base building and manufacturer involvement. The technology-base building thrust should address problems such as carbonate loss, single-cell performance decay, cathode solubility, anode creep, tile stability, contaminant effects, and materials selection, as well as the integration of fuel cells with coal gasifier. It is particularly important that this integration consider the gasifier and its impact on gas composition to yield an overall system optimization.

The manufacturer involvement should emphasize the testing of stacks built with the technology currently available in order to provide feedback to the independent R&D groups to further broaden the technology base and improve future stack design.

The current Federal molten carbonate fuel cell program must be re-focused and re-directed to provide these two parallel thrusts. The technology-base building thrust should involve independent R&D groups through multiple and parallel funding to stimulate the whole technical community for innovations and to provide cross-checking of results. Specific problems to be addressed include:

- Carbonate Loss/Management - The ion conducting media is either lost or redistributed, resulting in cell performance losses.
- Anode Creep - The porous electrode slowly densifies due to the compressive forces, resulting in cell performance losses.
- Separator Plate Corrosion - The metallic sheet separating the anode and cathode gases oxidizes and forms poorly conductive layers which impede current flow.
- Cathode Strength and Dissolution - This electrode is a weak structure which shows unacceptable solubility in the carbonate electrolyte at higher operating pressures.
- Electrolyte Matrix Cracking - Thermal expansion differences between the ceramic matrix and the electrodes cause the matrix to fracture leading to deleterious mixing of the reactant gases.

A comprehensive program must be focused on identifying solutions to the above problems and their interrelationships. Potential solutions to some problems exacerabate others.

The endurance or life test program should involve mainly manufacturers.

Specific targets include:

- Gas Manifold Design - Uniform flow to all cells must be achieved while maintaining good sealing and minimum electrolyte wicking from the individual cell components.

- Uniform Cell Performance - The quality control specifications (and component manufacturing techniques) to attain uniform (±10 mV) cell performance must be established.

- Temperature Control - The flow configurations, cell design, and cooling methods must be established to maintain a more uniform temperature distribution in the stack.

- Cost-Effective Cell Configuration - Vendor expertise in powder metal/porous metal structures, metal forming, and continuous ceramic molding techniques should be integrated into advanced and more cost-effective cell configurations.

- Endurance Testing - Endurance testing of selected cell configurations should be demonstrated in 20- to 100-cell stacks having cell areas of 1 to 3 square feet prior to further scale-up activities.

Q. In your estimation, how long will it take to solve those problems and commercialize the technology?

A. With proper restructuring and sustained support, it is possible that, in 5 years, the molten carbonate fuel cell can be brought to initial commercialization in the testing of a 200-kw prototype.

Q4. Congress has spent a great deal of time recently examining various legislative proposals dealing with decontrol of our natural gas supplies.

What impact do you believe that decontrol would have on our nation's development of unconventional gas supplies?

What impact would decontrol have on industry's willingness to use various new gas technologies?

A. The effect of decontrol on gas supply is very complex. It is not clear that the decontrol of oil has increased oil exploration or production. What Congress must provide is the proper climate for encouraging a steady, long-term deliverability of gas. To ensure this, the vast resources of unconventional gas must be technically ready to be tapped. Sustained continued R&D funding for tight formation R&D to understand the complex geology and provide technologies for predicting future production would substantially reduce the risk in development with private capital. Key parameters that need to be defined experimentally include the dependence of capillary pressure and relative permeabilities to gas and to water on fractional water content in the pore space. Similarly, coal-seam gas and geopressured gas need sustained R&D support to make these resources available for gas supply. Advanced technologies and improved understanding of the unconventional gas resources would reduce the uncertainty of exploration and hasten the time when industry will tap these vast resources.

Q5. The DOE Geopressured program is funded in a separate program outside the fossil energy programs. Do you believe it will be helpful to consolidate all of the DOE unconventional gas programs within one separate office?

A. Yes, I believe such consolidation would be helpful.

Q6. Over the years we have all become very aware of the potential of energy conservation. How has your budget been developed in order to reflect the pros and cons of both the more efficient utilization of our gas resources as well as the need to produce sufficient gas supplies to meet our nation's future energy needs?

A. As an R&D performing organization, IGT's budget depends on the budgets of the funding agencies. There must be a balance between gas supply and gas utilization R&D, and between long-term and short-term R&D. Gas supply R&D through the long-term must include coal gasification, unconventional gas, and renewable resources. Efficient gas utilization through the long-term must include advanced gas engines, high-temperature thermal recuperation, advanced combustors and burners, fuel cells, and advanced gas heat pumps.

Q. Do you believe that the DOE program adequately reflects an appropriate balance between the energy conservation programs and the natural gas supply programs?

A. The DOE program does not reflect the important role of gas in supplying one-fourth of the nation's energy. DOE funds 15 times more R&D related to electric power than gas-related R&D. This gross imbalance must be rectified. Toward this end, the $150 million gas-related R&D program recommended by the gas industry is the minimum level to be included in the FY 1985 DOE budget.

Q7. Over the years the Committee has been very concerned about the need for more efficient technology transfer between the Department and private sector users of new technology. Would you please comment on effectiveness of technology transfer in the DOE fossil programs?

A. While DOE has made new technologies available to the private sector, the actual deployment of such technologies has been infrequent. In addition to more intensive publicizing by DOE of new technologies, incentives should be provided to promote transfer to the private sector.

Q. What do you believe are some of the significant technical or institutional barriers which still remain in commercializing new natural gas technologies?

A. The main barrier to commercialization is DOE's policy of cutting off development too early in the overall chain. A technological gap is created when development stops arbitrarily at the "proof-of-concept" stage before the technology is demonstrated commercially for wide acceptance. This gap must be bridged by DOE assuming support all the way through commercial demonstration.

Q. Do you feel the DOE patent policy is well-suited to encourage the commercialization of natural gas technologies developed by the DOE programs?

A. The current DOE patent policy is acceptable, and much improved over previous ones.

Q8. While our hearing focused on the DOE R&D programs, the Committee has been extremely interested in how the new technologies developed under these programs have been used in the commercial sector. In this regard, would you please comment on how effective you believe the Synthetic Fuels Corporation has been in fulfilling its mission?

A. Overall, the SFC has yet to carry out the mandates of the Energy Security Act for which it was created. SFC's mission is to build a synthetic fuels industry to provide national security insurance. It is the charter of SFC to assume, not avoid, the risks for the private sector in starting a synthetic fuels industry for the nation. Indeed, the absence of prompt positive decisions by the SFC for the construction of synfuels production capacity contributes to the nation being virtually as vulnerable to energy disruptions today as it was in 1973.

Further, the SFC has not met its target of deploying a diversity of process technologies or of utilizing a diversity of resources. Although the bulk of our coal resources are in the East, close to the market with water and labor infrastructure, no eastern coal project, for either gas or liquid, has been accepted. In terms of processes, the two coal projects accepted both use entrained gasification processes that are so alike that ownership of portions of the technology is being contested between Dow and Texaco, the two process owners. No advanced fluidized bed gasification processes, which are more efficient and accept all ranks and all sizes of coals, especially eastern bituminous coals, have been selected. Likewise, no advanced moving bed gasification processes are included.

Clearly, the mission of the SFC remains as essential to the welfare of the nation today as it was perceived to be when the Energy Security Act was framed by the Congress. What is needed is for the SFC to more aggressively and innovatively pursue fulfilling its charter. The SFC was created to take bold actions to stimulate and foster a new energy industry that would make America potentially energy independent through utilization of our indigenous resources. Indeed, the need for accomplishing the goals of SFC is as urgent as ever, especially since we have lost a whole decade through inaction.

DON FUQUA (Fla.), Chairman

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Minority Staff Director

April 9, 1984

Mr. William Morse
Director of Research
Columbia Gas Systems
Columbus, Ohio 43216

Dear Mr. Morse:

Thank you for your testimony before the Subcommittee on Energy Development and Applications on March 8, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 30. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

DON FUQUA
Chairman

DF:kcw
attachment

AGA American Gas Association

1515 Wilson Boulevard, Arlington, Va. 22209
Telephone (703) 841-8400

May 1, 1984

The Honorable Don Fuqua
Chairman
Subcommittee on Energy Development and Applications
Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

With regard to your letter of April 9, 1984, to A.G.A.'s witness, Mr. William Morse, Columbia Gas System, we are providing the attached information in response to your questions. We hope they contain the information that your Subcommittee was seeking. If we can be of any further assistance in any way please don't hesitate to contact me (841-8616) or Jim McCarthy (841-8590) of my staff.

Sincerely,

Robert K. Boyd
Director
Congressional Relations

cc: William Morse

attachments

1. Q. Congress has spent a great deal of time recently examining various legislative proposals dealing with the decontrol of our natural gas supplies.

   What impact do you believe that decontrol would have on our Nation's development of unconventional gas supplies?

   A. Unconventional gas supplies such as geopressured brines, Devonian shales and coal seams have already been decontrolled pursuant to the Natural Gas Policy Act of 1978. In addition, gas from tight formations will remain under NGPA price controls but is eligible for an incentive price ceiling. Currently, tight formation gas is often sold at prices below the NGPA ceiling level for this category. Therefore, the decontrol proposals currently under consideration would not directly affect the prices paid for gas from unconventional sources. Upon decontrol, as stipulated by the NGPA, average wellhead prices are not expected to increase sharply. However, in the long term, as inexpensive, old gas sources are gradually depleted, increased prices will encourage the development of additional supplies from unconventional sources. In terms of costs, these unconventional sources compare favorably with a number of other gas supply alternatives.

   Q. What impact would decontrol have on industry's willingness to use various new gas technologies?

   A. Decontrol has enabled certain types of unconventional gas to be produced economically in some areas, enabling technology development which may not have otherwise occurred. Substantial additional technology development is needed to further expand production from these sources. As old, low-cost gas supplies are depleted, it is in the national interest to insure that the technology is available to bring forth most economically additional unconventional supplies at marketable prices. Certainly, the natural gas industry would use the available technologies to supply such gas.

2. Q. The DOE Geopressured program is funded in a separate program outside the fossil energy programs. Do you believe it will be helpful to consolidate all of the DOE unconventional gas programs within one separate office?

   A. We recognize that DOE may have very good reasons for administering the geopressured program separately from other fossil energy programs. However, we do point out that related programs that are centrally administered generally encounter fewer difficulties in reaching coordinated goals than do decentralized programs. Therefore, it appears that central administration of all the unconventional programs would facilitate coordinated and complementary R&D efforts. Central administration would also promote the efficient utilization of technological skills. Therefore, we would encourage DOE to consolidate the geopressured program with the fossil energy program.

3. Q. Over the years we have all become very aware of the potential of energy conservation. How has your budget been developed in order to reflect the pros and cons of both the more efficient utilization of our gas resources as well as the need to produce sufficient gas supplies to meet our nation's future energy needs?

A. The most important point to be made about natural gas R&D efforts is that there should be dramatic increases in the technological development of both gas supply and gas utilization. Overall, the federal government can develop supply technology more effectively than the private sector can. Thus, we feel that this is the area in which federal interests should play a leading role. On the other hand, the gas industry can be more effective than the federal government in developing utilization technologies. Therefore, we anticipate playing a more active role in this area than the federal government.

Natural gas from non-conventional sources supplements the gas produced from conventional sources, which currently represent the bulk of producible gas. Although gas supplies from conventional sources are plentiful, they will decline somewhat by the year 2000. To meet the balance of demand, we must produce increased amounts of natural gas from non-conventional sources. We estimate that these non-conventional sources can supplement conventional sources so that demand can be met. However, to exploit fully these non-conventional sources, vigorous R&D efforts must be undertaken. Our budget recommendations reflect our estimates of the appropriations necessary at present to carry out these vigorous R&D efforts.

With respect to more efficient energy utilization technologies, we acknowledge that the gas industry's goal is to sell as much natural gas as possible. However, alternative energy sources are currently marketed at prices that are very competitive with gas. As a result, consumers with the capacity to choose between energy sources make their choices based upon economic considerations. If they choose to use alternative fuels, then, of course, the gas industry loses the opportunity to sell its product. Consequently, the natural gas industry must offer a product that is the rational economic choice among energy sources. One way to accomplish this goal is to offer products that use gas very efficiently, thereby partly offsetting relatively high unit prices by lowering the total dollar cost to the consumer of the energy supply. Our recommendations have taken into consideration the technologies that are necessary to develop utilization equipment that uses gas in extremely efficient ways. We believe that, in addition to allowing the natural gas industry to retain its load, this equipment will use a valuable natural resource in an efficient manner. Moreover, these efficiencies will "stretch" our natural gas supplies, allowing a greater number of consumers to benefit from gas use for a longer time.

Q. Do you believe that the DOE program adequately reflects an appropriate balance between the energy conservation programs and the natural gas supply programs?

A. DOE's recommendations for authorizations for energy conservation programs, expressed as a percentage of total funds recommended, are relatively the same as A.G.A.'s recommendations. In that respect, we do not believe that DOE's balance between energy conservation and natural gas supply is inappropriate. However, the more critical issue appears to be whether DOE's recommendations would adequately fund conservation efforts. By our calculations, DOE recommends appropriations of $15.9 million for gas-related conservation programs and $7.9 million for gas-related fuel cell development. In contrast, A.G.A. recommends $22 million and $20 million, respectively. We believe that the recommendations of the natural gas industry, which are discussed in detail in the written testimony that was submitted by the Institute of Gas Technology and the Gas Research Institute, would fund conservation technologies at a level that is necessary to derive full benefits from these areas.

4. Q. Over the years the Committee has been very concerned about the need for more efficient technology transfer between the Department and private sector users of new technology. Would you please comment on effectiveness of technology transfer in the DOE fossil programs.

What do you believe are some of the significant technical or institutional barriers which still remain in commercializing new natural gas technologies?

Do you feel the DOE patent policy is well-suited to encourage the commercialization of natural gas technologies developed by the DOE programs?

A. Current DOE policy is to continue research through "proof-of-concept." However, the point at which the decision is taken is not objectively defined, and different persons or groups will make markedly different determinations. We feel that DOE currently concludes its research early, before the concepts are proven to the point where industry believes that the risks have been reduced such that further significant investment is prudent. In short, demonstrations of technical viability are not enough to induce widespread investment; economic viability must also be shown.

This problem is exacerbated by the existence of only two widely disparate modes of government support for new natural gas technologies. DOE performs proof-of-concept work as discussed above, and the Synthetic Fuels Corporation (SFC) is charged with supporting projects on a large commercial scale. Unfortunately, technical reality is such that the gulf between laboratory scale and large commercial scale is extremely wide. This is the gap normally filled by a graduated sequence of pilot and demonstration plants, where the basic commercial module can be proven.

Although the demonstration scale is not as capital-intensive as large-scale commercialization, it is still very expensive. The current economics of synfuels, DOE's tendency to turn over technology prematurely, and the large capital investment required for even demonstrations of new gas technologies inhibit the private sector from pursuing them. There is a definite need for government support in this area. DOE has recently indicated a willingness to provide "last resort" cofunding for semi-works projects; however, there are currently no funds allocated for such purposes. Thus, we are forced to conclude that DOE's technology transfer policies are in need of improvement.

In general, the DOE has not been very effective in commercialization efforts, but this appears to be due to the difficulty that the federal government faces in utilization technologies. As we noted in our response to question three, the DOE would be more effective if it were to focus its attention on long-term, high-risk supply technologies. This would allow the private sector to complement the DOE's efforts by doing what it does best: focus on utilization technologies.

With regard to the DOE patent policy, we note that an emphasis on and liberal application of developing patents will allow some investors to make sizable profits. This should not be viewed in a negative light. The profits generated by patent development would be an excellent indication of the success of the technologies involved. Since successful technologies should be the DOE goal, we believe that the DOE should follow a liberal patent policy. It should not stifle the development of patents by becoming hamstrung with concerns over the meticulously equitable allocation of the benefits derived from newly developed patents.

5. Q. While our hearing focused on the DOE R&D programs, the Committee has been extremely interested in how the new technologies developed under these programs have been used in the commercial sector. In this regard, would you please comment on how effective you believe the Synthetic Fuels Corporation has been in fulfilling its mission?

A. Through its budgetary authority, the Synthetic Fuels Corporation has awarded price guarantees to the Great Plains Coal Gasification Project. We applaud the SFC for this award, which the gas industry considers essential for orderly development of coal gasification technology. As a general proposition, we point out that rate-regulated utilities have special needs that are not encountered by other entities. Rate-regulated utilities have a disincentive to undertake large, high-risk projects. That is, if the project is successful, many benefits, including increased energy supply, go to the ratepayers. If the project is unsuccessful, it may be excluded from the rate base by a regulatory commission as an "imprudent" investment. In such a case the equity sponsors, including the shareholders of participating utiltities, bear the capital losses.

Because rate-regulated utilities face greater obstacles than nonregulated entitities in capital formation, several SFC policies tend disproportionately to encumber the prospects for assistance to synthetic fuels projects sponsored by rate-regulated utilities. These policies include: (a) high equity participation requirements; and (b) commercialization emphasis on large-scale projects.

The Memphis medium-Btu coal gas project is an example of a rate-regulated project that has not been encouraged by the SFC. Its successful completion would provide a "role model" for replication of its technology by rate-regulated utilities.

Overall, the SFC has been slow to act and has lacked direction at times. We believe that the SFC must be encouraged to make timely decisions based on objective economic analysis. For developing synthetic fuels technologies (i.e., "second generation" coal gasification), there continues to be a need for federal support for those stages of development between the DOE R&D programs and the commercialization programs sponsored by the SFC so far. Without this support, the capability to produce synthetic fuels in the future may be severely limited. We therefore believe that either the SFC or the DOE should support such technical demonstration projects.

DON FUQUA (Fla.), Chairman

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Minority Staff Director

April 9, 1984

David C. Webb, Senior V. P.
Policy and Regulatory Affairs
Gas Research Institute
Washington, D.C. 20036

Dear Dave:

Thank you for your testimony before the Subcommittee on Energy Development and Applications on March 8, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 30. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

Don

DON FUQUA
Chairman

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DAVID O. WEBB
Senior Vice President,
Policy and Regulatory Affairs

April 24, 1984

The Honorable Don Fuqua, Chairman
Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Fuqua:

Attached are my answers to your written questions from the March 8, 1984, hearing before the Subcommittee on Energy Development and Applications. If you desire further information, please don't hesitate to contact me.

I appreciated the opportunity of testifying again before your subcommittee and appreciate the support you have given to the Gas Research Institute.

Sincerely,

David O. Webb

David O. Webb

Attachment

RECEIVED
APR - 6 1984
COMMITTEE ON SCIENCE
AND TECHNOLOGY

Gas Research Institute, 8600 West Bryn Mawr Avenue, Chicago, Illinois 60631 312/399-8100

DRAFT

RESPONSE TO QUESTIONS FROM
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
SCIENCE AND TECHNOLOGY COMMITTEE
HEARING OF MARCH 8, 1984

1. You recommend funding for the Westinghouse Waltz Mill, Pennsylvania gasifier in fiscal year 1985. Does GRI plan to consider support for this facility again? When?

   GRI is currently discussing with DOE and Westhinghouse the possibility of resuming participation in the Waltz Mill project. This participation, if agreed to, will begin in late 1985 or early 1986.

2. You recommend $5 million for methane from coal seams. What type of program would you recommend DOE carry out?

   GRI is currently working with some coal seams located in Alabama and Colorado. To complement GRI's program, it is recommended that the Department of Energy pursue work in multi-seam programs in Pennsylvania, West Virginia, Ohio, and Virginia. No duplication would occur between the programs being done at GRI and DOE. These programs should include mine safety and in-mine drainage. Some longer term recommendations would include horizontal drilling technology, developing seismic techniques to characterize coal seams, further development of hydraulic fracture modeling to prevent fractures from damaging roof rock in coal seams and improved reservoir permeability modeling

3. Congress has spent a great deal of time recently examining various legislative proposals dealing with the decontrol of our natural gas supplies. What impact would decontrol have on our nations' development of unconventional gas supplies? What impact would decontrol have on industry's willingness to use various new gas technologies?

   Decontrol will accelerate the development of conventional gas supplies with primary emphasis on in-field drilling to produce old gas from known reservoirs. Therefore, the impact of decontrol would be to delay introduction of new technologies since the current surplus of gas would probably extend through the 1980s. However, all projections of lower-48 natural gas supplies incidate that by the mid-1990s, significant quantities of supplemental sources will be required to meet demand. In order to meet the demand of the 1990s and after, there is a viable government role in developing these supplemental sources by the early 1990s so the technologies will be in place when they are needed.

4. The DOE Geopressured program is funded in a separate program outside the fossil energy programs. Do you believe it will be helpful to consolidate all of the DOE unconventional gas programs within one spearate office?

   Yes. They should be consolidated in the fossil energy program. Currently the emphasis on the geopressured program is the generation of electricity from thermal resources including the generation of wellhead electric power from geopressured resources. However, only minimal efffort is being expended to investigate the many questions associated with production of methane in this resource. By consolidating this program with fossil energy, there could be more concentration on the benefits of producing methane from this vast resource.

5. Over the years we have all become very aware of the potential of energy conservation. How has your budget been developed in order to reflect the pros and cons of both the more efficient utilization of our gas resources as well as the need to produce sufficient gas supplies to meet our nation's future energy needs? Do you believe that the DOE program adequately reflects an appropriate balance between the energy conservation programs and the natural gas supply programs?

In response to the federal energy policy and since it promises the most potential in the near term for ratepayer benefits, GRI's funding for research in efficient utilization has received the largest budget increase, from a level of $38.9 million in 1982 to a level of $67.7 million in 1984 or approximately 55 percent of GRI's total R&D budget of $120 million.

DOE, in its FY 1985 budget request used the following figures:

| | FY 85 Budget Authority |
|---|---|
| Coal | $ 177.99 million |
| Petroleum | 31.60 million |
| Gas | 8.55 million |
| Policy & Management | 54.73 million |
| | $ 272.87 million |
| Conservation | $ 162.15 million |

While it appears that gas is an extremely small percentage of the budget, there is some research being done in other categories which benefits the gas industry. There is approximately $67 million in gas-related research found in the combined programs of coal, gas, petroleum, and renewables. There is definitely an imbalance between conservation and gas supply research requests. But while the balance between conservation and gas is 2.5 to 1, the real imbalance comes between gas- and electric-related research dollars. There are structural problems inherent in both the gas and electric industries; i.e., they are regulated, price-controlled industries, often selling their products not at free market prices, but at controlled prices which are below replacement costs. DOE's Energy Research Advisory Board, in a report to the Department of Energy, put these factors in proper perspective in its study entitled, Federal Energy R&D Priorities which states, "Both these regulated industries have weak incentives to spend on R&D. If successful, the benefits go to ratepayers; if unsuccessful, the expenditure may be disallowed as 'imprudent'." In its FY 1985 budget request, DOE recognized this problem for the electric utilities by proposing a total electric-related research budget of approximately $1,320 million. However, they totally ignored these same institutional and structural deficiencies for the regulated gas industry by proposing only $83.7 million for gas-related research. While there is significant differences in the cost of electric versus gas R&D, a ratio of 15 to 1 is unjustified. This imbalance must be corrected by funding a sound and consistent gas-related research program.

6. Over the years the Committee has been very concerned about the need for more efficient technology transfer between the Department and private sector users of new technology. Would you please comment on effectiveness of technology transfer in the DOE fossil programs. What do you believe are some of the significant technical or institutional barriers which

still remain in commercializing new natural gas technologies? Do you feel the DOE patent policy is well-suited to encourage the commercialization of natural gas technologies developed by the DOE programs?

One of the major barriers was mentioned in the question above, that being the fact that the gas industry is a regulated industry with weak incentives to spend on R&D. If successful, the benefits go to ratepayers; if unsuccessful, the expenditure may be disallowed as imprudent. A second institutional barrier is the lack of a consistent federal policy and continued funding for ongoing projects. A major problem is the inability of industry to anticipate the federal role, level of funding, and research that will be supported from one budget cycle to the next. Industry, especially the regulated sectors of the energy industry, cannot rapidly respond to abrupt changes in federal energy R&D policy or budgets. As an example, GRI's acitvities are planned and funded through a mechanism requiring public review and comment prior to approval by the FERC. This precludes the gas industry, through GRI, from rapidly shifting or increasing its R&D funding. Industry requires a stable and consistent federal base against which to plan its own research programs.

A third institutional barrier to commercializing new natural gas technologies is industry's focus on near-term benefits from research. GRI's emphasis on near-term research has resulted in significantly increased cofunding from the manufacturing sector. Industry coordinated funding has increased from a level of $8.8 million in 1979 to approximately $31 million in 1983. However, GRI's experience with industry cofunding strongly indicates the majority of these coordinated funds will always be in areas that have the potential to be commercialized within five years. A balanced, consistent federal policy that provides adequate funding for long-term gas research is absolutely essential if industry is to assume the near-term research previously funded by the federal government.

7. While our hearing focused on the DOE R&D programs, the Committee has been extremely interested in how the new technologies developed under these programs have been used in the commercial sector. In this regard, would you please comment on how effective you believe the Synthetic Fuels Corporation has been in fulfilling its mission?

Obviously, the Synthetic Fuels Corporation is moving slowly in carrying out its mission since it has only the Cool Water Gasification project under contract. If the reason for not contracting for more projects is that they don't meet the criteria, then perhaps the charter for the SFC is too narrow to bridge the gap between the Synthetic Fuels Corporation's activities and what government and industry are doing.

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
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HAROLD P. HANSON
Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID S. JEFFERY
Minority Staff Director

April 9, 1984

John Robert Friday, Vice Pres.
Research and Development
Lummus Crest
Bloomfield, New Jersey 07003

Dear Mr. Friday:

Thank you for your testimony before the Subcommittee on Energy Development and Applications on March 8, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 30. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

DON FUQUA
Chairman

DF:kcw
attachment

**Lummus Crest Inc.**
A Subsidiary of
Combustion Engineering, Inc.
1515 Broad Street
Bloomfield, New Jersey 07003

Tel. 201/893-1515
Telex: 138198

April 12, 1984

Mr. Don Fuqua, Chariman
Committee on Science and Technology
U. S. House of Representatives
Rayburn House Office Building
Suite 2321
Washington, D. C. 20515

Dear Mr. Fuqua:

We appreciated the opportunity to testify before the Subcommittee on Energy Development and Applications on March 8, 1984. Our responses to your additional questions are attached.

We believe it is important that an effective level of support for coal liquefaction development continue. If you require any additional information or have any further questions regarding my testimony, please let me know.

Very truly yours,

LUMMUS CREST INC.

J. R. Friday
Vice President
Engineering Development Center

JRF:gdv
Attachment

## LUMMUS CREST INC.

## RESPONSE TO SUBCOMMITTEE QUESTIONS

1. What is the annual cost of operating the Lummus Crest two-stage liquefaction facility? What portion would industry be willing to share?

   The total cost of operating the Lummus Crest two-stage liquefaction facility is $6,000,000 per year. We are willing to share 15 percent of that cost, or $900,000 per year.

2. Do any other facilities exist where DOE or industry could get the same data that your facility provides?

   An important aspect of our proposed program is the use of multiple reactors for different functions in the liquefaction process and solvent generation. Our facility is small enough to allow inexpensive reordering of our multiple reactors. No other facility exists, to our knowledge, with this capability.

3. After completion of your recommended R & D program, what would be the next step in developing two-stage liquefaction technology?

   We believe that the next step following our program would require substantial scale-up in order to demonstrate some aspects of the process. However, if the situation required commercialization on an urgent schedule, it might be possible to skip this step by combining our experience with other coal liquefaction technology.

4. In your testimony you state, "Liquefaction of coal will become economically attractive in the United States when the price of crude oil increases significantly above the present level."

   In your opinion, is it technology or the price of oil that is the desincentive for the establishment of liquefaction plants in this country?

   No coal liquefaction plants are being planned or built today because of the low price of crude oil and its general availability. However, every analyst agrees that forecasting oil prices is a highly uncertain undertaking. We believe it is important that our country not allow coal liquefaction activities to lie completely dormant since significant advances are possible and will retard the inevitable loss of capability associated with total shutdown.

5. Haven't the large pilot plants, using the Exxon Donor Solvent process, the H-Coal process, and the SRC-11 process, adequately demonstrated the technology of the liquefaction process?

   The Lummus Crest Integrated Two-Stage Liquefaction (ITSL) process has been widely recognized as technically superior to the large pilot plant process mentioned in your question; e.g., the sponsors of the H-Coal process have publicly acknowledged the superiority of two-stage liquefaction to their own process. We believe that our program will enhance in an important way the ITSL technology.

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
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General Counsel
DAVID S. JEFFERY
Minority Staff Director

April 9, 1984

Frank C. Schora, President
HYCRUDE
10 West 35th Street
Chicago, Illinois 60616

Dear Mr. Schora:

Thank you for your testimony before the Subcommittee on Energy Development and Applications on March 8, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 30. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Kcw
attachment

HYCRUDE™

FRANK C. SCHORA
PRESIDENT

10 W. 35TH STREET, CHICAGO, ILLINOIS 60616
GENERAL PHONE 312/567-5900
FOREIGN TELEX 6871080
U.S. TELEX 256189

April 27 1984

The Honorable Don Fuqua
Chairman
Subcommittee on Energy Development and Applications
House Science and Technology Committee
Rayburn House Office Building
Suite 2321
Washington, D.C. 20515

Dear Mr. Chairman:

Attached is the answer to the question submitted to me to supplement the record of my testimony before the Subcommittee on Energy Development and Applications on March 8, 1984.

Thank you for the opportunity both to testify on Eastern oil shale and to supplement my earlier testimony.

Sincerely,

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jp/
Enclosure

A Subsidiary of GDC, Inc.

**QUESTION**

The Committee has heard testimony recently on the promise of the vast Eastern oil shale resources. Do you believe the DOE budget provides a true balance in supporting the development of our Western as well as our Eastern oil shale? If not, what technical activities do you believe would be appropriate for the Federal Government to support in developing our Eastern oil shale resource?

**Answer**

Federal expenditures on Eastern and Western oil shales are not balanced. In fiscal year 1982 alone Federal expenditures on Western U.S. oil shales were approximately $19 million. This is in contrast with the total Federal expenditures to date on Eastern oil shale, which amount to approximately $6 million. Eastern U.S. oil shale is a significant resource which could ultimately supply our Nation with over 400 billion barrels of synthetic crude oil, and the resource is located in an areas which contains an established social infrastructure, process water, oil refining capacity and end markets.

Because Eastern oil shales do not respond as favorably to conventional retorting processes as Western shales, a research program to continue the development of technologies which improve the economics and efficiency of synfuels recovery from Eastern oil shales is necessary. Such a program will provide data in a form that can be readily utilized by process developers in future design efforts. Research efforts should be designed to significantly improve and/or modify existing Eastern shale retorting processes and to investigate new, yet to be proven technology. Much of the program presented below will also lead ultimately to improvements in the processing of Western shales.

Detailed research suggestions for FY '85 would include the following:

The inclusion of fundamental research projects in the program will ensure the continued entry of new process concepts designed specifically for full utilization of Eastern U.S. oil shales. Because the Eastern U.S. oil shales do not respond as favorably to conventional retorting processes as Western U.S. oil shales, a fundamental research program is necessary to search for new technologies which will improve the economics of synfuels recovery from Eastern U.S. oil shales, and to provide published information on Eastern U.S. oil shales which can be utilized by process developers in their design efforts.

- Conduct tests to broaden the range of raw shale fines which can be processed by moving-bed hydroretorting, thereby reducing waste and improving process economics and resource utilization.

- Investigate the use of mist formation to control droplet size and minimize refluxing in counterflow systems.
- Investigate novel methods for processing fines which will increase the efficiency and improve the economics of oil recovery.
- Identify the primary reaction products of Eastern U.S. oil shale and ionized gases to develop better understanding of shale retorting chemistry.
- Develop environmentally-acceptable methods for direct combustion of Eastern shale. The ability to burn raw or spent Eastern shale will contribute to more complete energy recovery should thermal methods be used for oil recovery.
- Continue investigation of fast heatup fluidized bed retorting, which in preliminary testing has shown promising oil yields.
- Test various atmospheres (hydrogen, steam, methane, carbon monoxide, etc.) to optimize operating conditions for enhanced oil yields.
- Investigate the gasification characteristics of Eastern U.S. oil shales.
- Perfect analytical and petrographic techniques which will aid in the chemical characterization and geological classification of oil shale.
- Develop biological processes for removing the sulfur and nitrogen from shale oil produced by retorting Eastern U.S. oil shale.
- Establish a data book of physical and chemical properties of Eastern U.S. oil shale which will aid in the development of process designs.
- Investigate methods for oil shale beneficiation, which concentrates the organic content of an oil shale and results in a greatly-enriched oil shale feedstock.

An advanced research program as outlined below will enable continued progress for processes which have relatively near-term (within the next decade) prospects for commercialization.

Three major types of processes are applicable to Eastern U.S. oil shale retorting: existing Western U.S. conventional thermal processes, hydroretorting, and new technologies. Only the latter two require significant work in the advanced research program. Western U.S. oil shale processes are well-documented and their limitations in retorting Eastern U.S. oil shales are known.

A selection of program elements for moving-bed hydroretorting and the newer technologies designed to evaluate and/or improve the economics of Eastern U.S. oil shale retorting is outlined below:

- Evaluate technology for crushing raw Eastern U.S. oil shale to produce closely-controlled size fractions with minimized energy consumption and fines loss.
- Study methods for reducing hydrogen consumption in moving-bed hydroretorting, which will improve the process economics by reducing both capital and operating costs.
- Evaluate the economic feasibility of various methods of physical and chemical beneficiation (enrichment) techniques.
- Perform a sensitivity analysis of components of shale mining, crushing, and processing systems for moving-bed hydroretorting to identify areas in which research and cost improvement efforts will have the greatest benefit.
- Construct an experimental unit to test and optimize conditions for feeding raw shale and discharging spent shale at elevated pressure.
- Conduct hydroretorting assays, continuous moving-bed heat of reaction hydroretorting tests, and solids and products chemical analyses on various shales to broaden the design data base for the moving-bed hydroretorting process.
- Study scaleup issues (oil yield versus equipment size) for fast heatup, fluidized-bed thermal retorting of Eastern U.S. oil shale.
- Conduct a market study to identify users of Eastern U.S. shale oil produced by moving-bed hydroretorting for chemical feedstocks, JP-4, etc., and project prices and potential market size.
- Develop and test improved methods such as electrical fields for separating water and fines from the oil product.
- Develop methods for gasification of raw shale fines and retort residues to improve the overall efficiency of energy recovery in Eastern shale retorting.

35-837 O—82——86

During FY'86 DOE funding should be directed toward further support of the research initiatives begun in FY'85. Experimental and development work should concentrate on the following areas:

- Utilization of fines - Larger-scale proof-of-concept tests of fines injection into moving-bed hydroretorting reactors should be conducted. The use of high-pressure, heated hydraulic presses which enable use of the kerogen itself as a binder should be examined as a way of re-constituting fine raw shale for feeding along with normal size shale particles. Investigation of the gasification of oil shale fines to produce $H_2$ should continue.

- Shale Preheating - Proof-of-concept tests of the effectiveness of shale preheating concept in enhancing oil yield and reducing $H_2$ consumption in moving-bed hydroretorting should be conducted, using adiabatic equipment to provide more realistic simulation of commercial-scale operation.

- Beneficiation - Using techniques developed in FY'85, sufficient beneficiated Eastern oil shales should be prepared to enable continuous testing of moving-bed hydroretorting processes on the beneficiated shale.

- Design Studies for Integrated Moving-Bed Hydroretorting Process Test Facility - Work should begin on assessment of the design and cost aspects of construction of an integrated test facility for the moving-bed hydroretorting process. Such a facility would incorporate continuous, integrated, adiabatic operation of all parts of a commercial moving-bed hydroretorting reactor, including both solids and gas flow and chemical reactions in a single unit.

During FY'87 we recommend assessment of the results of the program detailed above, and concentration on those areas which show greatest prospects for successful transfer to private industry and eventual commercialization.

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
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TOM LEWIS, FLA.

HAROLD P. HANSON
Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID S. JEFFERY
Minority Staff Director

April 9, 1984

Joseph A. McElwain
Chairman of the Board
Montana Power Company
40 East Broadway
Butte, Montana 59701

Dear Mr. McElwain:

Thank you for your testimony before the Subcommittee on Energy Development and Applications on March 8, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 30. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Kcw
attachment

MONTANA POWER COMPANY mpc GENERAL OFFICES 40 EAST BROADWAY BUTTE MONTANA 59701 • TELEPHONE 406/723-5421

JOSEPH A. McELWAIN
CHAIRMAN OF THE BOARD
AND
CHIEF EXECUTIVE OFFICER

April 25, 1984

Mr. Don Fuqua
Chairman
U.S. House of Representatives
Committee on Science
and Technology
Suite 2321 Rayburn House
Office Building
Washington, D.C. 20515

Dear Mr. Fuqua:

I appreciate the opportunity to provide additional information to my testimony given before your Subcommittee on Energy Development and Applications on March 8, 1984, in support of developing the Magnetohydrodynamics (MHD) Technology.

Enclosed is the response to the "Questions for Mr. McElwain" from your April 9, 1984 letter. I am hopeful that this information will be beneficial and contribute to a positive evaluation of MHD.

Yours truly,

Joe McElwain

JAM/FEW/sv/B:2

Enclosures

QUESTIONS FOR MR. MCELWAIN

1. As you may be aware, the Committee, over the years, has been extremely concerned about the lack of a comprehensive MHD program plan. Do you believe this criticism has now been addressed? If not, would you please describe what needs to be further addressed?

   Answer: The "lack of a comprehensive MHD program plan" has been addressed verbally by the Department of Energy (DOE). I view the current dialogue being fostered with the utilities and private sector on the MHD program by DOE Assistant Secretary for Fossil Energy, Mr. Vaughan, as a means of establishing a comprehensive MHD program plan. However, I still have concerns about the length of time such an iterative, committee-like process will take and the inability of DOE to commit to a multi-year MHD program that will attract cost sharing -- a DOE requirement.

2. The Department has indicated that they plan to proceed with a proof-of-concept MHD project. What are your comments on this proposed activity? Do you believe this activity is justified at the present time? If so, please comment.

   Answer: I agree that the advancements in the state-of-the-art in MHD justify proceeding to a proof-of-concept MHD project at this time. MHD's track record in meeting its milestones is well known and my summary of achievements in the testimony indicate the significance of these advances. This proof-of-concept facility should bring all the parts together in an integrated facility, preferably at a utility site. The size must be sufficient to address the technical phenomena that occurs with scale up, as well as large enough to address the risks involved in the additional scale up required for a commercial plant.

   Such a proof-of-concept plant would probably take five to eight years to design, construct and startup. Parallel with this activity, the core program of research and development, of the components has to be taken to completion. The work initiated in previous years and carried on this year, at both the CDIF and CFFF in regards to coal comb stor, channel, HRSR and downstream development, would be completed at the same time as the initial design stages of the proof-of-concept project. Both aspects of this program, the core program and the proof-of-concept program, are timely and necessary to take the MHD technology to useful completion.

3. Why is the 80 megawatt thermal system suggested by DOE too small, as you state in your testimony? What size would you suggest? What would be the relative costs of the two types of facilities? What portion of either facility would industry be willing to cost share? Isn't the large facility a much more risky investment?

Answer: The 80 megawatt thermal system is too small for several reasons, both technical and financial. A few are listed below:

1) Very little new information would be gained over the current 50 $MW_t$ program.

2) The controllability of the facility is a major concern because the energy coupling between the MHD topping plant and the steam bottoming plant is too weak.

3) The weak energy coupling and small size may be insufficient to develop the interactive affects that each individual component will have on each other in a full sized plant.

4) The energy level at 80 $MW_t$ may be too low to achieve a viable proof-of-concept situation.

5) Technological phenomena that can be encountered in scale-up cannot be addressed or demonstrated at this level.

6) Significant industry cost sharing has little potential at this size.

7) No proprietary positions can be established to promote the necessary industrial supplier base.

8) The total costs to develop MHD would be significantly increased and time schedules extended many years if this approach were taken.

A retrofit in an existing commercial location seems to be the best alternative to allow both cost sharing and the minimal cost investment by the federal government. The size of this plant would have to be of technically appropriate scale. It has to be site specific and there would be other specific requirements. My testimony sites one acceptable case. Nominally, a size approaching the 250 $MW_t$ thermal, as proposed by the MHD Industrial Forum is needed. The larger size system might be the same net cost to the government as a smaller size. For example, indication from the Department of Energy is that the estimate for the 80 megawatt plant suggested in their program is about 150 million dollars. That is for both a topping and bottoming unit. Those same 150 million dollars applied to a retrofit could be used to greatly increase the size of the facility, and with cost sharing from the sponsoring utility and the industry, be able to attain more meaningful data. There is some additional risk in scale-up to a larger facility, but the potential savings in time and dollars to MHD development justify this risk.

4. The Committee is funding a number of programs aimed at developing new and more efficient electric technologies, such as magnetic fusion, inherently safe nuclear reactors, fuel cells, more efficient fluidized bed reactors, renewable electric options, etc. Where do you believe MHD will fit in with these other technologies in meeting our nation's utilities future electric needs?

Answer: MHD electrical power generation has the potential of being the most efficient, environmentally acceptable method to directly burn coal -- our most abundant fuel resource. I see MHD as a "base-load" power plant option by the turn of the century. Only with the maximum use of coal can we sever our dependence on foreign oil and using coal in the most efficient manner extends the availability of coal as a fuel for many years.

This country needs all these power sources. We need a family of energy systems able to operate on a variety of energy forms. Therefore, comparing the fossil energy programs with the nuclear programs or the fusion programs is inappropriate when a balanced energy supply is the goal. In a national energy policy plan (NEPA-IV), the goal is to have adequate, balanced energy supply at reasonable cost.

Within fossil energy, there are actually two revolutionary technologies being developed - MHD and fuel cells. The other technologies have to do with product improvement. The only place large efficiency jumps are indicated are with MHD and fuel cells. Each offers advantages. MHD, with its coal-firing, its ability to use a variety of coals with high sulfur content and no frontend clean up, etc., makes MHD unique. For the utilization of coal, MHD development is more advanced and cost effective than the third generation of fuel cells, which may be able to use the synthesized gas from coal vs. the clean fuels now required. It is not unreasonable for the Department of Energy to be supporting the development of both these technologies, because they do compliment each other and do fit in with the national goal. Each of the technologies, MHD and fuel cells, aims at a different market. MHD is aiming at the base load ability of a large power plant, whereas near-term fuel cell application is in cogeneration and in time, may be in modular base load. MHD is one of the only technologies, or one of the few, that promises greatly reduced $NO_x$ and $SO_x$ with reduced life cycle costs and cost of energy from the coal-firing. The concerns over the environment and environmental intrusion will not go away.

Any research and development on future energy requirements that internalize our energy capability should be encouraged. My personal experience in 30 years with the electric industry is that fusion is as far away today as when I started; even though it was predicted to be available in 40 years. I am a strong proponent of using our vast coal reserves. It will be the MHD technology or one very similar to it, that in fact, will lead us into the future with lower costs of electricity, increased use of our resources and a more efficient use of those resources.

DON FUQUA (Fla.), Chairman

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April 9, 1984

S. R. Hart, Jr., Vice President
Research and Development
Southern Company Services, Inc.
Birmingham, Alabama 35202

Dear Mr. Hart:

Thank you for your testimony before the Subcommittee on Energy Development and Applications on March 8, 1984. Attached are some additional questions that Members of the Subcommittee would like you to answer, in order to supplement the record of the hearing on this topic.

I would appreciate your responses to the hearing questions by April 30. If you have any questions regarding this request, please contact Mr. Robert Kripowicz, Subcommittee Staff Director, at (202) 225-4494.

Sincerely,

Don Fuqua

DON FUQUA
Chairman

DF:Kcw
attachment

Southern Company Services, Inc.
Post Office Box 2625
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**S. R. Hart, Jr.**
Vice President

*the southern electric system*

April 24, 1984

The Honorable Don Fuqua, Chairman
Committee on Science and Technology
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington DC 20515

Dear Congressman Fuqua:

Attached are answers to the questions from Members of the Subcommittee on Energy Development and Applications which you submitted with your letter of April 9, 1984. We appreciate this opportunity to supplement the record of the hearing of March 8, 1984 relative to the Wilsonville Advanced Coal Liquefaction Research and Development Facility. We will be happy to provide any other information about this subject if you desire.

Sincerely,

S. R. Hart Jr

S. R. Hart, Jr.

me:0374h

Attachment

cc/att: U.S. House of Representatives
Mr. Robert Kripowicz

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APR [illegible]0 1984
COMMITTEE ON SCIENCE
AND TECHNOLOGY

### *ANSWERS TO QUESTIONS SUBMITTED BY CONGRESSMAN DON FUQUA TO MR. S. R. HART, JR. ON APRIL 9, 1984, RELATIVE TO THE WILSONVILLE ADVANCED COAL LIQUEFACTION RESEARCH AND DEVELOPMENT FACILITY*

1. *In your testimony you state "liquefaction of coal will become economically attractive in the United States when the price of crude oil increases significantly above the present level." In your opinion, is it technology or the price of oil that is the disincentive for the establishment of liquefaction plants in this country? If it is the latter, to what level must oil prices rise to make coal liquefaction economically attractive?*

*Answer:* The Wilsonville program is not expected to produce a "breakthrough" which will allow direct coal liquefaction to compete with crude oil priced at $30 to $35 per barrel. It is expected to produce a data base that can be used to design a two-stage process to produce a given product whenever economics and/or national commitments permit. Because petroleum fuels have been and could again be used as a political tool, we believe continued development of synthetic fuel technologies is important for other than economic considerations. In summary, we do not believe that potential liquefaction technology is the disincentive for establishment of coal liquefaction plants in the United States, but rather the uncertainty of future economics which may not be the product of pure supply-demand conditions. Thus we cannot predict when direct coal liquefaction products can be economically competitive with petroleum products.

2. *Haven't the large pilot plants, using the Exxon Donor Solvent process, the H-Coal process, and the SRC-II process, demonstrated the technology of the liquefaction process?*

*Answer:* The large pilot plant projects produced data about mechanical equipment design that can be used by any direct liquefaction process. In addition, the three processes mentioned and the SRC-I process have demonstrated what products can be produced by single-stage direct liquefaction processes. However the single-stage direct process products may not be economically competitive with higher grade products expected to be available from the two-stage process.

3. *What are the advantages of two-stage liquefaction as opposed to previously developed processes such as SRC-I and II, H-Coal, and Donor Solvent?*

*Answer:* In general, two-stage liquefaction produces more distillate fuel and less gaseous fuel than a single-stage process. Wilsonville has demonstrated that integrated two-stage liquefaction produces a higher distillate yield with a lower consumption of expensive hydrogen than first generation processes. Furthermore, the solids separation process used at Wilsonville has achieved a greater recovery of desirable fuels than other solids separation processes. The quality of fuels from two-stage liquefaction are superior to fuels produced by single-stage processes. Combustion tests on fuels from Wilsonville have shown that two-stage fuels can directly replace petroleum fuels and also reduce emissions of sulfur compounds.

4. *After testing in the Wilsonville facility, will two-stage liquefaction be ready for commercial demonstration?*

*Answer:* The program planned for Wilsonville includes variability studies at each of the process units and process modeling work which would be completed by the end of 1986. By using the completed data base from Wilsonville and the large-scale mechanical design data from the large pilot plant projects, the data base is expected to be adequate for the design of a commercial two-stage process.

5. *The Wilsonville plant has been in operation gathering data on the liquefaction process since 1974. What additional and significant data will be collected for the next two years which require the continued operation of the plant?*

*Answer:* While Wilsonville has been investigating direct liquefaction for ten years, the first seven years of research were directed at the single-stage SRC-I process. Research into two-stage liquefaction did not begin until 1981. Research through 1986 is needed to collect data on the effects of variables such as temperature, pressure and flow conditions on individual unit performance. These data are needed to complete process modeling that is essential for demonstrating and understanding two-stage liquefaction.

*What effect would the immediate termination of the Wilsonville plant have upon the value of the data gathered to date?*

*Answer:* Data generated to date would lose significant value for future use. Currently the data are in the form of discrete points. These data cannot be used to predict what product slates can be expected from operation at conditions that were not tested. Modeling of individual process units is an essential step before the presently unrelated data can best be understood. The data would then be in a form suitable for utilization in future commercialization efforts.

6. *How much cost sharing will your company be willing to commit to the operation of the facility?*

*Answer:* The Southern electric system will contribute more than $16 million to the Electric Power Research Institute (EPRI) in 1984. Through our memberships on the EPRI Board of Directors and several key committees we will continue to exert strong influence to have EPRI continue its $3.5 million per year support of the Wilsonville facility. Southern Company Services will continue to provide overall management of the project at no cost to DOE or EPRI. These services will cost about $225,000 in 1984 and will increase our company's contributions to more than $5.5 million since beginning the project in 1972.

7. *What relationship does the Lummus Crest facility in New Jersey have to the Wilsonville, Alabama facility?*

*Answer:* The general objective of the Wilsonville and Lummus programs is to develop integrated two-stage liquefaction technology. However there are certain aspects of the plants that make the programs very different. The Lummus facility is about one-tenth the size of the Wilsonville pilot plant. It is very difficult to collect steady-state data at plants significantly smaller than Wilsonville. The Lummus process uses a short-contact time thermal reactor for the first-stage conversion of coal and anti-solvent deashing technology for settling of the coal solids. The Wilsonville plant is more flexible than the Lummus unit because it can investigate a wider variety of thermal reaction times. In addition, Wilsonville uses a critical solvent deashing process to remove solids. This process permits rapid and very efficient separation of solids from coal products while further providing the flexibility to investigate a variety of potentially attractive two-stage configurations. Both the Lummus and Wilsonville systems upgrade products from the first-stage in a second-stage catalytic reactor. However, the Wilsonville pilot plant has the additional capability of maintaining constant process performance by the addition of fresh catalyst and withdrawal of spent catalyst from the second-stage reactor.

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